UTILITIES MAN 1 & CHIEF

NAVY TRAINING COURSES

NAVPERS 10657-B

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Reprinted with major changes 1959

PREFACE

This training course has been prepared for the use of men, both regular Navy and Naval Reserve, who are studying for advancement to the rates of Utilities Man First Class and Chief Utilities Man.

Recent changes in the rating concept have made foremanship responsibilities the most important factor in these two rates. The text of this present edition of *Utilities Man 1 and C* has been completely reorganized and rewritten, to emphasize the distinction now made between service ratings and general ratings.

Two new subject matter areas appear in the present text: the installation and servicing of galley equipment, in chapter 6; and the basic combat organization, and small unit combat tactics, in chapter 11. A chapter on small unit combat tactics will appear hereafter in all Navy training manuals for Construction Battalion petty officers first class or chief. The chapter on galley equipment, however, really belongs in the training manual for *Utilities Man 3 and 2*, but this factor was added to the Quals too late for coverage in NavPers 10656-C.

As one of the Navy training courses, this book has been prepared by the U. S. Navy Training Publications Center, for the Bureau of Naval Personnel. Technical assistance has been rendered by the Bureau of Yards and Docks; by the Utilities Man School, NAVSCON, Construction Battalion Center, Port Hueneme; and by various other personnel of the Naval Establishment specially cognizant of the equipments and operational procedures at advanced bases.

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends. the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

ACTIVE DUTY ADVANCEMENT REQUIREMENTS

<table>
<tr><th>REQUIREMENTS*</th><th>E1 to E2</th><th>E2 to E3</th><th>E3 to E4</th><th>E4 to E5</th><th>E5 to E6</th><th>E6 to E7A</th><th>E7 to E8</th><th>E8 to E9</th></tr>
<tr><td>SERVICE</td><td>4 mos. service—or completion of recruit training.</td><td>6 mos. as E-2.</td><td>6 mos. as E-3.</td><td>12 mos. as E-4.</td><td>24 mos. as E-5.</td><td>36 mos. as E-6.</td><td rowspan="4">48 mos. as E-7. 8 of 11 years total service must be enlisted. Must be permanent appointment.</td><td rowspan="4">24 mos. as E-8. 10 of 13 years total service must be enlisted.</td></tr>
<tr><td>SCHOOL</td><td>Recruit Training.</td><td></td><td>Class A for PR3, HM3, DT3, PT3.</td><td></td><td></td><td>Class B for AGCA, MUCA.</td></tr>
<tr><td>PRACTICAL FACTORS</td><td>Locally prepared check-offs.</td><td colspan="5">Records of Practical Factors, NavPers 760, must be completed for E-3 and all PO advancements.</td></tr>
<tr><td>PERFORMANCE TEST</td><td colspan="2"></td><td colspan="4">Specified ratings must complete applicable performance tests before taking examinations.</td></tr>
<tr><td>ENLISTED PERFORMANCE EVALUATION</td><td colspan="2">As used by CO when approving advancement.</td><td colspan="4">Counts toward performance factor credit in advancement multiple.</td><td colspan="2">Special evaluation required.</td></tr>
<tr><td>EXAMINATIONS</td><td colspan="2">Locally prepared tests.</td><td colspan="4">Service-wide examinations required for all PO advancements.</td><td colspan="2">Service-wide and selection board.</td></tr>
<tr><td>NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)</td><td></td><td colspan="5">Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.</td><td colspan="2"></td></tr>
<tr><td rowspan="2">AUTHORIZATION</td><td colspan="2">Commanding Officer</td><td colspan="3">U.S. Naval Examining Center</td><td colspan="3">Bureau of Naval Personnel</td></tr>
<tr><td colspan="6">TARS are advanced to fill vacancies and must be approved by CNARESTRA.</td><td colspan="2"></td></tr>
</table>

*All advancements require commanding officer's recommendation.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*		E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
	FOR THESE DRILLS PER YEAR						
TOTAL TIME IN GRADE	24 OR 48	9 mos.	9 mos.	15 mos.	18 mos.	24 mos.	36 mos.
	12	9 mos.	15 mos.	21 mos.	24 mos.	36 mos.	42 mos.
	NON-DRILLING	12 mos.	24 mos.	24 mos.	36 mos.	48 mos.	48 mos.
DRILLS ATTENDED IN GRADE#	48	27	27	45	54	72	108
	24	16	16	27	32	42	65
	12	8	13	19	21	32	38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48	14 days	14 days	14 days	14 days	28 days	42 days
	12	14 days	14 days	14 days	28 days	42 days	42 days
	NON-DRILLING	None	None	14 days	14 days	28 days	28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation by commanding officer required for all advancements.
#Active duty periods may be substituted for drills and training duty.

READING LIST

NAVY TRAINING COURSES

Utilities Man 3 and 2, NavPers 10656-C
Refuse Disposal, TP-Pu-1
Storm Drainage Systems, TP-Pw-1
(Parts C and D)
Power Generation and Distribution, TP-Pu-3
(Chapter 4)
Water Supply Systems, TP-Pw-12
Basic Mechanical Engineering, TP-Te-4
(Part B)

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer.*

Number	Title
C 760	Plumbing
B 769	Introduction to Mechanical Drawing: I
B 770	Introduction to Mechanical Drawing: II

*"Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials, if the orders calling them to active duty specify a period of 120 days or more or, if they have been on active duty for a period of 120 days or more, regardless of the time specified in the active duty orders."

CONTENTS

UTILITIES MAN

1 & C

CHAPTER 1

NEW DUTIES AND RESPONSIBILITIES

The tasks assigned to Naval Construction Forces require knowledge and skill in a number of occupational areas. The Seabee must be able to work with a wide variety of equipment, under a variety of conditions. On occasion, his equipment may be limited rather than varied, but he must nevertheless meet the challenge of producing the desired results with what means are available to him. Often his work must be accomplished at an off-continent base, in a totally unaccustomed environment.

Almost any construction or maintenance job involves unexpected problems: lack of necessary supplies or personnel; unforeseen obstacles arising out of the nature of the terrain, or of the climate; interference from hostile forces; accidents that immobilize needed equipment.

Faced with obstacles of this sort, the petty officer must be competent to make a quick evaluation of the situation, decide upon the most practicable course of action, and use all his resourcefulness to accomplish the assigned tasks in spite of difficulties. The Navy expects a great deal from every first class and chief petty officer, and the way in which you meet these demands is the measure of your success as a petty officer.

You have already learned the three important factors in Navy service: knowledge, teamwork, and leadership. With each upward step that you take in your rating, an ever broader scope of knowledge, an expanding ability in teamwork and in leadership, will be required of you.

A promotion from a service rating to the general rating carries with it a special type of responsibility. In addition to performing the practical factors required of your new rate, you will have increasing responsibility for planning and supervising the work of lower-rated men, and of arranging programs for cross-training the service rating personnel for advancement to the general rating. These new duties will demand of you a mastery of your technical field or fields, a facility for sharing this knowledge with others, and the ability to get assigned jobs done correctly and on time.

TECHNICAL RESPONSIBILITIES

Your service rating as a Utilities Man Second Class gave you a specialty—either in the field of water supply and sanitation, or as Plumber, Boilerman, or Refrigeration and Air Conditioning specialist. To advance to a general rating, you must not only be proficient in your specific service rating, but you must also be ready, in a general way at least, to operate in the special fields indicated by the other service ratings for Utilities Man. Until you have a good grasp of the information areas in all the applicable service ratings, and can perform the practical factors, it will be virtually impossible for you to plan work schedules in these various fields, and to train and supervise the work performance of lower-rated men.

Qualifications for Advancement

In appendix II of this training course, you will find the qualifications for the individual rates in the Utilities Man rating. These quals represent all corrections made through Change No. 11, and are those current at the time this text was prepared for the printer. Before taking an examination for advancement, you should refer to section VIII of the *Manual of Qualifications for Advancement in Rating*, NavPers 18068 (Rev.).

The qualifications as given in appendix II indicate the recent changes that have been made in the rating structure itself. The quals are now divided into subject matter areas, and these "occupational areas" are further divided

into Practical Factors and Knowledge Factors. The Practical Factors relate to the actual performance of work operations; the Knowledge Factors to the principles and techniques that underlie satisfactory work performance.

The applicable rates (listed in the off-side column) indicate the lowest rate for which an individual qual is a requirement. The Utilities Man First Class must know everything that is required of his rate, and of a Third and of a Second Class; the Chief Utilities Man must know everything that is required of his rate, and of a Third Class, a Second Class, and a First Class. As previously mentioned, Utilities Man First and Utilities Man Chief are general ratings. Therefore, both as First Class and as Chief, you must know all that is required of each one of the four service ratings which make up the general rating of Utilities Man.

As soon as you qualify on a practical factor, a record of that fact is made on a standard NavPers form 760, Record of Practical Factors. A copy of this form is held by your company commander or your supervising officer, and is forwarded with your enlisted service record when you are transferred to another billet.

A duplicate copy of this form is provided each Navy man, so that he may maintain a personal record of his progress. It is advisable that you keep this copy of NavPers 760, and refer to it periodically; you will find it an excellent check-off list for all the factors, both military and professional, in which you must demonstrate proficiency before you can be recommended for advancement.

Military requirements are not ordinarily a part of a Navy Training Course, but the new quals introduced in Change No. 11 make it necessary for a man who wishes to qualify for Chief Utilities Man to have some understanding of combat formations and combat signals. These quals are the subject matter of chapter 11 of this training course.

Most of the additional information that you will need in order to qualify as a Chief Utilities Man, or as a First Class, relates to the supervisory responsibilities classified under the general heading, "Foremanship." Training an individual, or a crew, in techniques and operations,

arranging work schedules, and job control and supervision, are far more complex duties than the operation or maintenance procedures for mechanical equipment. These duties require that you constantly enlarge your field of knowledge, and train yourself to work cooperatively with others. The necessity for this self-development cannot be overemphasized.

Sources of Information

The types of equipment that must be operated by the Utilities Man are varied. The work operations themselves, and to a great extent the maintenance and repair procedures, are the responsibilities of Third Class and Second Class men, but the Chief Utilities Man and the First Class must be competent to instruct and supervise these lower-rated men.

It will be necessary for the Chief Utilities Man, and to a somewhat lesser extent for the Utilities Man First Class, to have a knowledge of the application of fundamental principles involved in the operation of available equipment. They must also be familiar with the subject matter of *Utilities Man 3 & 2,* NavPers 10656-C.

Although this training course is designed to give you the information that will be necessary to meet the requirements of the general rating, you can benefit greatly by acquiring other publications which deal with the various technical fields in which you must work.

Navy and Army Manuals

No one book of the size of the Navy Training Courses can carry all the worthwhile data on the installation, operation, and maintenance of boilers, pumps, refrigeration and air conditioning systems, water purification units, waste disposal plants, and so forth.

If you wish to become really expert, so that you can supply a workable solution for any difficulty that arises, you should try to get the publications listed below. Your company commander, or the education and training officer, may be able to assist you in getting these publications, which are obtained through normal supply channels.

Much of the equipment that you will use is of the type used by the Marine Corps and the Army, and therefore several Technical Manuals of the Army are included in this list of applicable references.

NAVY PUBLICATIONS:

**Basic Mechanical Engineering,* NavDocks TP-Te-4 (1 September 1954).

**Power Generation and Distribution,* NavDocks TP-Pu-3 (1953-1954).

**Water Supply Systems,* NavDocks TP-Pw-12 (1 February 1954).

Water Supply for Advanced Bases, NavDocks TP-PL-6 (1 November 1952).

**Storm Drainage Systems,* NavDocks TP-Pw-1.

Sewerage Systems, NavDocks TP-Pw-15 (1 May 1954).

**Refuse Disposal,* NavDocks TP-Pu-1 (1 September 1952).

ARMY PUBLICATIONS:

Operation of Water Supply and Treatment Facilities at Fixed Army Installations, TM5-660 (November 1952).

Military Water Supply and Purification, TM5-295 (August 1945).

Inspection and Preventive Maintenance Services for Water Supply Systems at Fixed Installations, TM5-661 (September 1945).

Operation of Sewerage and Sewage Treatment Facilities at Fixed Army Installations, TM5-665 (November 1945).

Refrigeration, Air Conditioning, Evaporative (Desert) Cooling and Ventilation, Repairs and Utilities, TM5-670 (July 1947).

Other publications that will be of considerable help to the Utilities Man operating in regions where pest control is an important factor, or to those who are assigned to polar or subpolar bases are:

Insect and Rodent Control (a joint Army-Air Force-Navy publication), AFM 85-7, TM5-632, NavDocks TP-Pu2 (1 February 1956).

Low Temperature Sanitation; this is one of a series of occupational briefs prepared in the office of the Chief of Naval Operations.

Of the publications already listed, several are prefaced by an asterisk. These are texts that are included in *Training Publications for Advancement in Rating,* NavPers 10052, as representing the bibliographies (or references) that will be used by examining authorities in preparing your examination for advancement in rating.

From time to time, this latter reference (NavPers 10052) is revised, and it is a good idea to consult the most recent issue before you take the advancement examination. The current issue (March 1958), lists *Power Generation and Distribution* as a reference for Chief Utilities Man and Utilities Man First Class, but indicates only one chapter (ch. 4), Power Plant Water Conditioning. The subject matter of this chapter is as follows:

1. Design and Construction, including discussion of chemical analysis, feedwater treatment, treatment plants, secondary internal treatment, and laboratory and testing equipment.
2. Operation and Maintenance, including discussion of external treatment plants, chemical testing procedures, care of idle boilers, corrosion prevention, safety precautions, and records and reports.

Copies of this publication may be obtained through normal channels of supply. Include the chapter number, the chapter title, and the TP number (TP-Pu-3) when making the request.

Another Navy publication that can be used as a guide in preparing training material for lower-rated men is the *Shipboard Training Manual* (a Special Purpose publication) NavPers 90110.

Military Requirements for Petty Officers 1 & C, NavPers 10057, is a book that you should have access to; this, and a companion text for Petty Officers 3 and 2, has now replaced the *General Training Course for Petty Officers,* NavPers 10055—a text with which you must already be familiar.

Manufacturers' Operating Manuals

When new equipment is procured by the Navy, it is practically always accompanied by a manual of operating

and maintenance instructions. Such books, referred to generally as manufacturers' operating manuals, should be kept available for reference. Most of these instruction books describe in detail the construction of the machine or equipment, and the procedures for operating it and for maintaining it in serviceable condition.

Present-day mechanisms are complex; it takes skill to properly install and operate them, and repairing them is oftentimes a very specialized type of job. It is decidedly to your advantage to learn what you can from the men who design and construct the equipment with which you work.

Technical Journals and Handbooks

Every man who works in a technical field has an interest in the journals that deal with his specialty. The Utilities Man, by the nature of his work, will naturally find many useful articles, and suggestions that he can incorporate into his own job, in the many technical publications that are issued by the Bureau of Yards and Docks. Several of these publications have been specifically mentioned under the section on Navy and Army Manuals. Others that might be mentioned here are:

U. S. Navy Civil Engineer Corps Bulletin, NavDocks P-2.

BuDocks Technical Digest, NavDocks P-23.

Advanced Base Manual.

The *Civil Engineer Corps Bulletin* is published monthly by the Bureau of Yards and Docks. It is distributed to all Civil Engineer Corps officers, Regular and Reserve. The *Bulletin* discusses Seabee operations, and various aspects of construction and maintenance of public works and public utilities of the Naval Shore Establishment.

The *Technical Digest* is published monthly, and is distributed to all Civil Engineer Corps officers on active duty. Several additional copies of each issue are made available to each Public Works Office and Mobile Construction Battalion for distribution within these organizations, to make them accessible to all personnel who wish to consult them.

The *Advanced Base Manual* is a text that was designed primarily for use in Naval Reserve Units. Although it

emphasizes the logistic problems involved in developing base sites, it nevertheless contains much information that will prove useful to the Utilities Man who is given an off-continent assignment.

The *Seabee Role Overseas*, a BuDocks publication, is also well worth reading. True, the procedures current when the text was prepared have undergone considerable modification in the ensuing years; but the book still has value as a guide to the man who is called upon to participate, with not much opportunity for additional training, in work at an advanced base.

ADMINISTRATIVE RESPONSIBILITIES

Perhaps the most important of your new responsibilities will be the supervision that you must exercise over the men assigned to you. Your technical responsibilities are easy in comparison—you master the necessary skills gradually, with increasing experience, and you learn the best sources to consult when you have a problem of balky equipment or inadequate supplies. In assuming your new authority, however, you will have to depend upon others, not upon yourself, to get a job done, and you will have to keep in mind the fact that training these lower-rated men is as important in itself as the job for which you train them.

In chapter 10 of this training course, there is a fairly detailed discussion of your duties toward the men assigned to you, and the necessity for the right attitudes in training them, and in planning, assigning, and supervising their work. However, since your value as a petty officer is so closely tied in with your supervisory duties, it is worth stressing the importance of making a good start.

One very important factor in planning and directing the work activities of other men is to know the job yourself. There is a wide range in the job of the Utilities Man, and consequently a great many things that you must be able to do. Some types of work you never had time to thoroughly master, perhaps, because of the pressure of more important duties; some work procedures you have forgotten, because you had so little need to practice them.

But if there is any doubt in your mind about a job that is part of your present qualifications, or of the qualifications for the lower rates, you will do well to go back to

the Navy Training Courses (especially *Utilities Man 3 and 2,* NavPers 10656-C), and brush up on doubtful points. Study the manufacturers' manuals, and any technical references that are available. Try to know the job before you attempt to instruct or supervise another man who is doing it.

Since giving orders will be a daily routine, learn to give them clearly and concisely. Any order presupposes that the man receiving it requires the instruction or the information contained. Be careful, therefore, to see that your order tells the man what he must know if he is to turn in a good performance—what is to be done, when he is to do it, how he is to do it, and (if it seems advisable) why he is to do it.

Somewhere you will have to make the adjustment between picking the best man for the job, and at the same time making sure that the second and third string men have a chance to develop proficiency. The ideal way would be to pick the best man when there is a need for haste in getting a job done, and to pick the man who needs the training when there is no priority on the work to be done.

In working with other Group VIII ratings, listen to the ideas that the men may have concerning the best way to accomplish an assigned task. Even when an idea will not work out in a given situation, it may have possibilities under a different set of circumstances. Ideas underlie all progress; never take the sort of high-handed attitude that will dry these ideas up at the source. As a petty officer in charge of a group of men doing a construction or maintenance job, you are going to have a heavy responsibility, and any help that you can get should be utilized for the good of the service.

In general, your program for any work assignment should follow a carefully thought-out plan that includes a logical division of work processes; an impartial choice of the men who will perform them; a clear explanation of what is expected of them; a check-up during the performance; encouragement to the men, in the form of praise for work well done, or of a patient and good-tempered correction when necessary; and a careful inspection of the final job.

You are a link in the chain of command, with a responsibility for getting assigned tasks accomplished, and

the added responsibility for sharing your knowledge, so that there will always be men ready and willing to do Navy tasks. The sense of responsibility that you bring to instruction and to supervision is as important to the Navy service as the responsibility that you would demonstrate in times of emergency or danger.

PRIDE OF SERVICE

The public works and public utilities, and the maintenance functions connected with them, that are the largest part of the Utilities Man's field of operation are similar in many ways to the equipment and the problems that arise at advanced bases. Navy personnel serving aboard ship carry their United States environment with them; the men of the Construction Battalions, on the other hand, must often meet the challenges of unfamiliar environment, unavoidable shortages of supplies, and primitive living conditions.

Your rating represents an important job that fills an immediate need in the over-all mission of the Seabees. No training course or manual can foresee and provide for the many situations that may develop. It is necessary, therefore, that the Seabee petty officers have self-reliance and resourcefulness.

Past achievements of the Seabees are such as to give you an honest pride in their traditions of accomplishment and service. This constructive type of pride is an important factor in promoting morale, efficiency, and teamwork within your organization.

The pioneer spirit of 19th Century America magically changed the face of the land, building communities and utilizing natural resources. On a small scale, the Construction Battalions may be called upon to repeat this type of achievement in a matter of a few short months. Figures 1-1, 1-2, and 1-3 show the sort of achievement that the Navy has already wrought, under the spur of need for advanced bases.

As a Seabee, you have an important function in the development of similar projects, from the first step when the staff determines the location and the requirements of a base until the base is an accomplished fact.

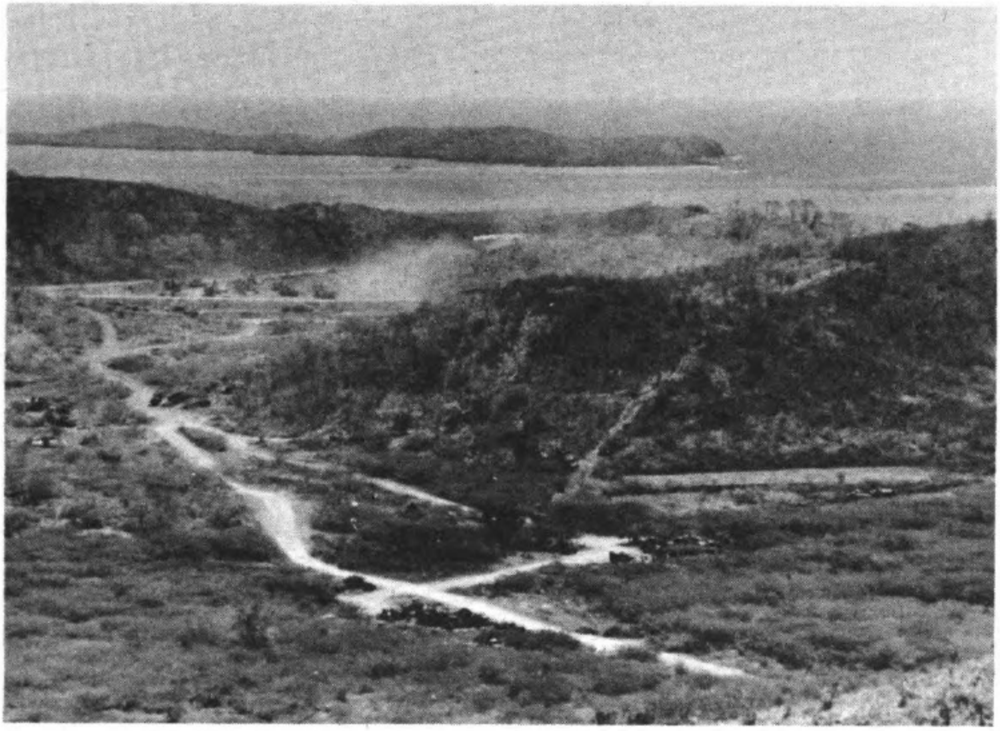


Figure 1-1.—Reconnaissance photo of a proposed base site.

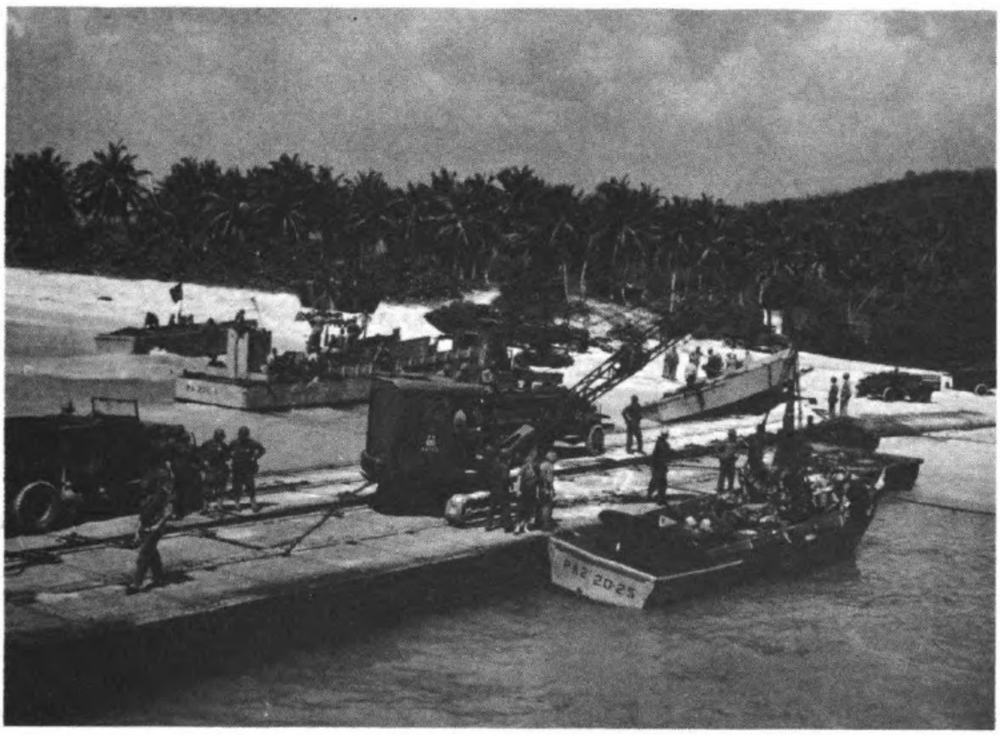


Figure 1-2.—Seabees unloading equipment on the beach.

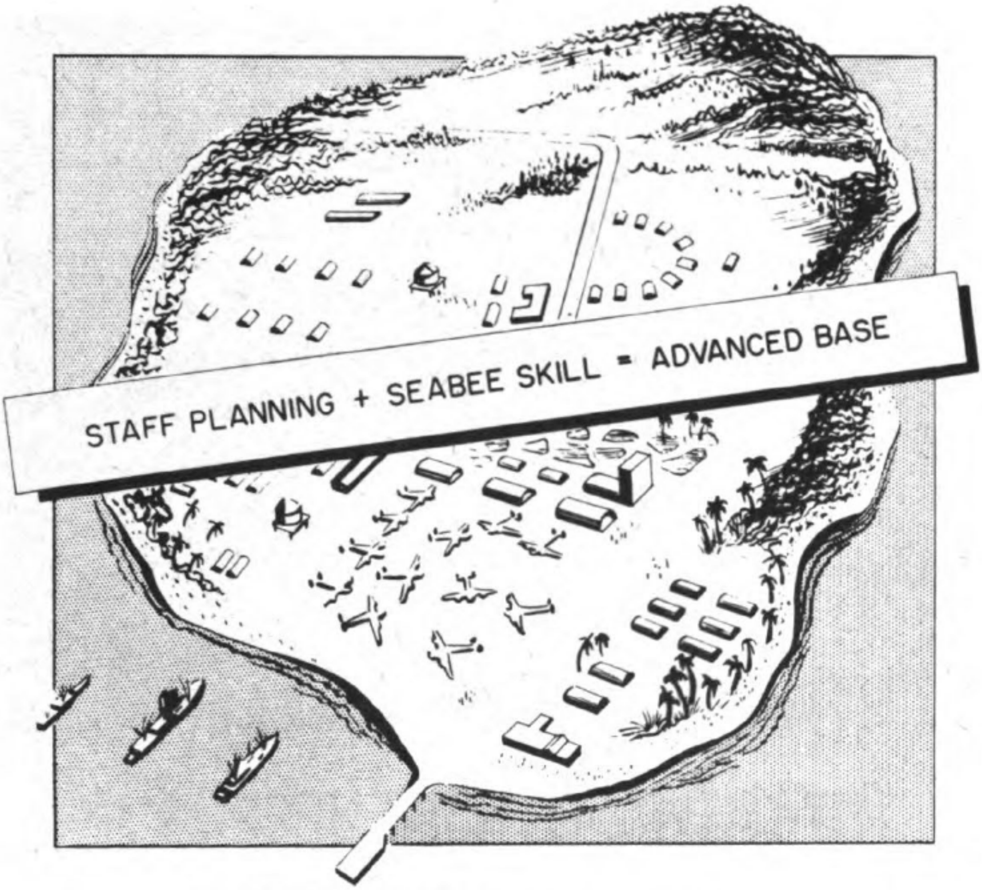


Figure 1-3.—The base established.

LEADERSHIP

Leadership ability is a major requisite for a successful career as Navy chief or first class. The characteristics of leadership are many, and not all people agree on what constitutes these characteristics. It might be said, with much truth, that leadership is best known by its lack; but this would not be a very practical way of developing leadership qualities.

How can you, on the positive side, fulfill this many-faceted requirement? Approach your job with honesty, integrity, and sincerity, and you will have the support and respect of your men. They will look upon you as their leader.

A few guidelines that may be helpful are offered. Your leadership is made evident in the success with which you can teach and train lower-rated men, and stimulate them to learn and to accomplish. Try to set an example of

what the ideal petty officer should be, both in military and technical competence.

What traits should you cultivate? Self-confidence, an attitude of cooperation, and a real interest in your men are probably the most important. Self-confidence must be based upon the knowledge that you are thoroughly competent in your technical field. A cooperative attitude involves willingness to share your knowledge of the job, and patience with the learner. An interest in your men is best expressed by your efforts to help them in their professional advancement in the service.

Leadership is a difficult ability to teach; it has to be developed rather than learned. But it is an ability that can be mastered; most of our best leaders are those who have been self-made.

QUIZ

1. What are the 3 important factors that make a successful petty officer?
2. The promotion from service rating to general rating carries with it what special type of responsibility?
3. Why is it necessary for a First Class or Chief Utilities Man to have a good knowledge of the practical factors in the UT service ratings qualifications?
4. Why is it advisable for the UT to consult Training Courses and Publications for General Service Ratings, NavPers 10052, when he is preparing for an examination for advancement in rating?
5. What 4 factors does the text suggest for inclusion in an order to a lower-rated man?
6. What traits will the Seabee petty officer most need in meeting unexpected situations?
7. What is the practical value of pride in your branch of service?
8. In what practical way are the leadership qualities of a petty officer made evident?

CHAPTER 2

BOILERS AND BOILER CONTROLS

At all Navy installations hot water and steam are required for the processes of cooking, cleaning, laundering, and sterilizing; at many installations, heating of small buildings also demands a supply of hot water or of steam. The boilers, therefore, fill an important function at any base. To operate these boilers at optimum efficiency, you must understand their construction, and the uses and proper maintenance of the fittings and controls.

In qualifying for the Utilities Man service ratings, you learned the construction and operating principle of steam boilers, the procedures for starting and securing, the setting and adjusting of burners and valves, methods for repairing or replacing defective tubes, and general maintenance of watersides and firesides. In the general ratings, you will have the responsibility for instructing, training, and supervising lower-rated men in these practical factors. Make your knowledge of boilers as comprehensive as possible, by reviewing the information in *Utilities Man 3 and 2,* NavPers 10656-C, as well as by study of the material in this chapter.

Boilers provided by the Navy for use at advanced bases are fire tube boilers, either vertical or horizontal, and operating at relatively low pressures. It is doubtful if a Utilities Man will ever be required to operate a water tube boiler. However, you can find considerable information concerning the basic design and the operation of water tube boilers in Chapter 12 of NavPers 10656-C.

Every boiler must have a combustion chamber, in which the necessary heat is generated; it must have a space for water; and it must have a space into which the steam can escape as it is generated.

The boiler proper consists of the following components: a heating surface, one side of which is in contact with the combustion gases, and the other side of which is in contact with water or wet steam; an inlet system for the boiler feedwater; and an outlet system for the steam. In addition, the boiler must be equipped with blowdown valves, with pressure and temperature gages, and with safety valves.

Small cast iron heating boilers and return tubular boilers (HRT) are almost always constructed with integral furnace or combustion chamber. The furnace enclosure, or setting, is refractory.

Heat release limits are set in accordance with such factors as the shape of the furnace, the nature of the refractory walls, the amount of boiler metal surface exposed to radiant heat, the type of grate, the nature of the fuel, the type of firing, the temperature of the preheated combustion air, and the admission of secondary air.

Inasmuch as the boilers used at advanced bases (whether the vertical fire tube or the horizontal fire tube type) are the so-called package boilers, the first four factors are fixed by the manufacturer; it is only the last four factors over which you will have any control.

VERTICAL FIRE TUBE BOILERS

A vertical skid-mounted low pressure boiler, similar to the one illustrated in figure 2-1, is available in two sizes: 250,000 Btu, and 595,000 to 808,000 Btu. These boilers operate on a single-phase 110-volt 60-cycle current. The working pressure of these boilers is 15 psi, but actual operating pressure should be held to about 10 psi.

A second type of vertical skid-mounted boiler, for general use as a source of steam at advanced bases, is the 150-psi 60-horsepower model shown in figure 2-2. This type of boiler is oil fired, but is readily convertible to coal firing.

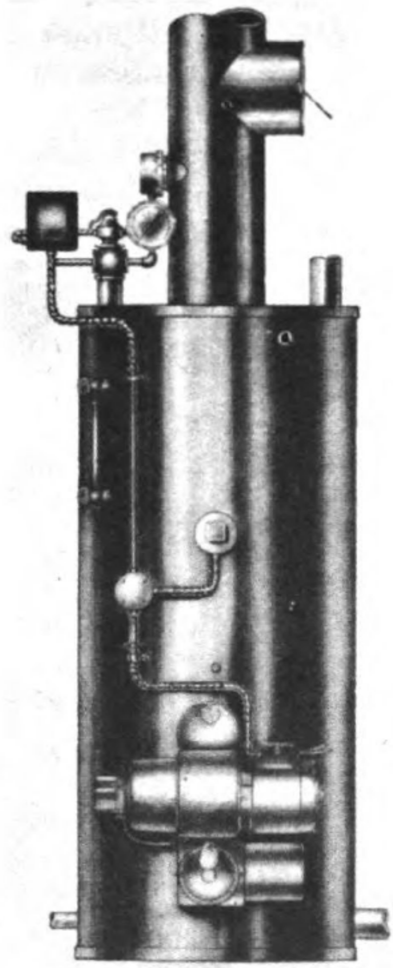


Figure 2-1.—Vertical fire tube boiler with maximum steam working pressure of 15 psi.

These boilers come with all accessories needed for safe and efficient operation. Equipment includes steam pressure indicating gage, safety valves, water gage glass, feedwater regulator, and low water cutoff.

Burners

On the 15 psi package boiler, the oil burner is already secured, in readiness for lighting off as soon as fuel line, flue, and electrical connections have been made. Drains, piping, blowdown valves, and other necessary valves are part of the original shipment.

The 150 psi boiler does not come in the same stage of readiness, since the insulating material and refractory

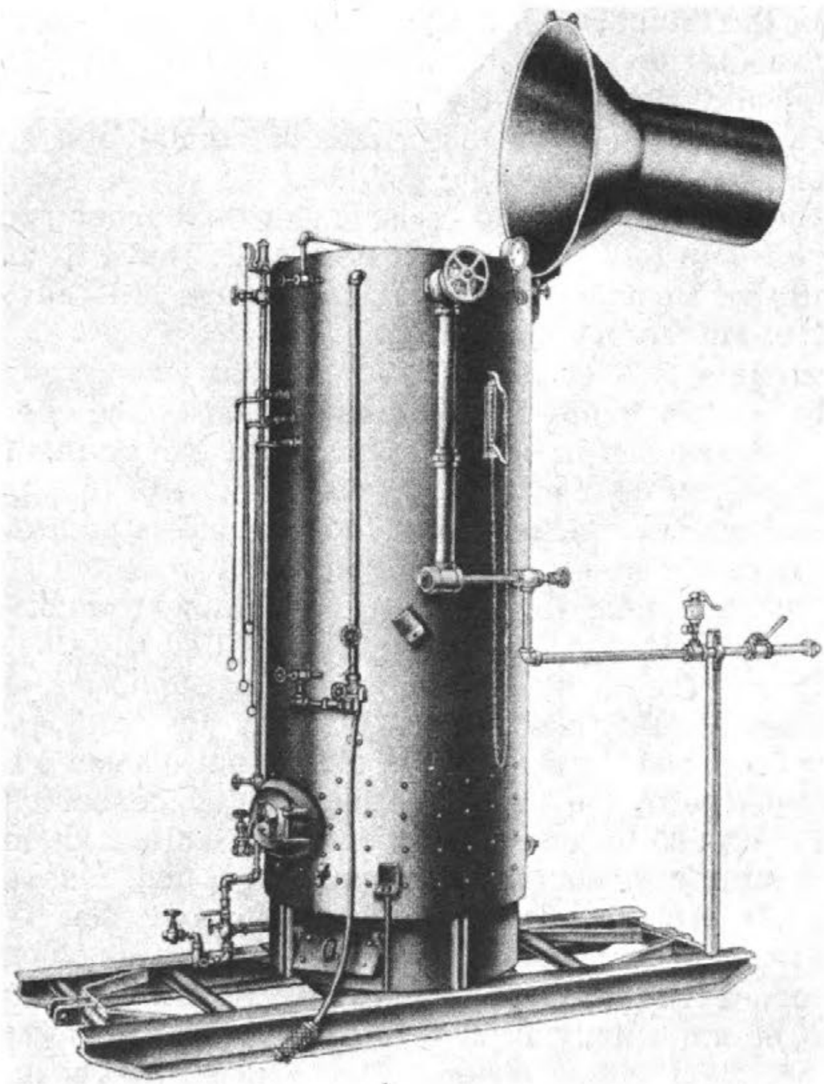


Figure 2-2.—Vertical fire tube boiler with maximum steam working pressure of 150 psi.

have to be installed at the base. However, the necessary material is supplied as a part of the boiler component.

The material includes insulating block, insulating cement, firebrick, firebrick cement, and refractory. The supply is sufficient for original lining of the combustion chamber, and for two relinings. The quantity of each material furnished provides a slight margin for spoilage or waste. When the combustion chamber is lined, the joint between the chamber and the bottom edge of the boiler shell must be sealed.

When the 150 psi boiler is put into operation, the burner flame should be symmetrically distributed. The flame itself should not touch the heating surface; adjust the burners so that only the hot gases of combustion come into contact with the heating surface.

If you are firing a cold furnace, let the burner run on low fire for 15 to 20 minutes, if possible. This will allow for uniform furnace expansion, and there will be less danger of refractory damage.

When this type of boiler is to be coal fired, you will have to use the grate that comes as part of the component. The grate is in sections, so that it can be inserted through the fire door without any disturbance of the boiler or the oil burner. Make sure that the grate is positioned securely on the steel supporting ring.

No storage tank for fuel oil, nor piping to make the connection from tank to boiler, is supplied with the 150 psi boiler. The arrangement made for supplying oil to the burner should take advantage of any possibilities for gravity feed, and the static head should not exceed 6 feet.

Included with the boiler fittings and accessories, in the 150 psi, 60 hp component, is an injector, an independent unit with suction hose, strainer, and necessary valves. In attaching the injector, make sure that it will be taking steam from the highest point in the boiler; never connect it with steam used for any other purpose.

The steam supply pipe that is smaller in diameter than the injector connection will work, if not kept in use for too long a period. The water supply pipe, however, must be AT LEAST AS LARGE as the injector fitting. The steam drain pipe also should be the full size of the injector connection, and may be larger.

When you are preparing to put an injector into operation, you must first give the steam pipe a thorough blowing out, to remove any dirt or scale. Inspect the suction hose to make sure that it is watertight and airtight; have it as straight as possible, and have the bottom of the hose completely under water. (The overflow pipe, on the other hand, must never be carried beneath the surface of the water.)

To start the injector, first open the valve in the water supply, and then open the valve in the steam pipe. Regulate the injector with the water supply valve, NOT with

the steam valve. Stop the injector by first closing the steam valve, and then closing the water valve.

Figure 2-3 illustrates the assembly of the large-sized (595,000 Btu) boiler. If supply voltage at the base differs from the 110-volts designated for the boiler's electrical components, a power transformer will be needed.

The burner assembly, indicated on the lower left-hand side of the illustration, is a compact unit containing all the necessary components.

The burner head contains a double nozzle burner, with adjustable twin electrodes for the ignition spark. The nozzle is of the high-pressure atomizing gun type. A blower wheel attached directly to the motor shaft is linked to the fuel unit by a flexible coupling.

The fuel unit consists of a strainer, a rotary pump, and a pressure regulator. Mounted as integral parts of the burner assembly are the ignition transformer, the electronic program relay, and the motor starting conductor.

The electronic program relay consists essentially of an electronic flame relay, a warp switch circuit, and a load relay which serves to control the powering of electrical boiler components.

The motor starting contactor is an electrical relay actuated by the control circuit to switch power to the motor. (The current requirements of the motor are greater than the contact rating of the electronic program relay.)

Controls

The control assembly (see fig. 2-3) is comprised of two indicators and two automatic controls. The indicators are: the gage glass, which indicates water level in the boiler; and the steam pressure gage, which indicates the steam pressure in the boiler. The controls are: the steam pressure control and the low water cutoff. Both the low water cutoff and the water gage glass are equipped with blowdown.

The steam pressure control is a bellows type, actuated by steam. A single-throw mercury switch breaks the power to the burner whenever steam pressure exceeds the control limit, and renews the power when the pressure drops back to the set operating range.

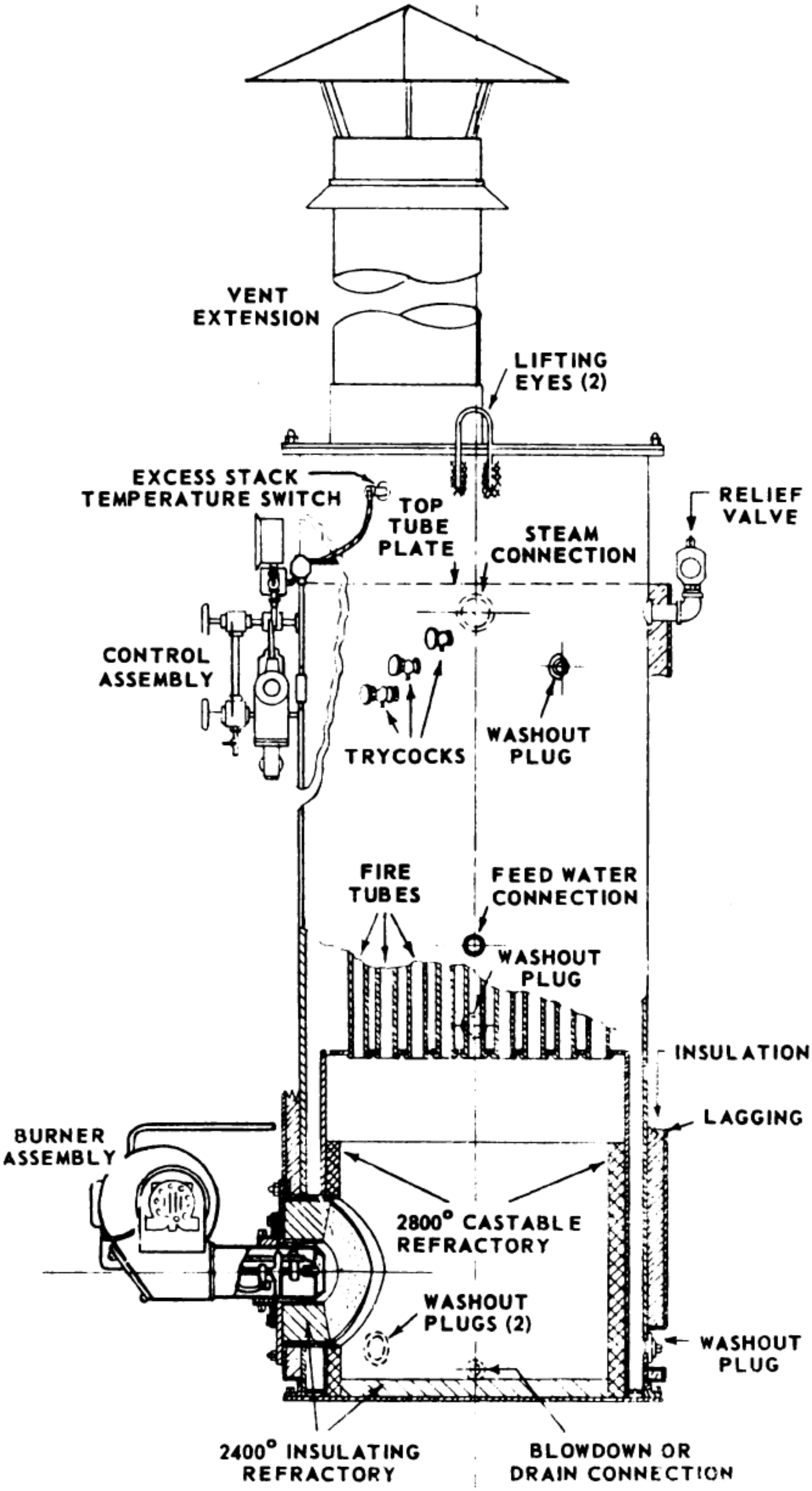


Figure 2-3.—Low pressure boiler assembly.

The low water cutoff is a float-operated switch. It functions to cut off power to the burner when the water level drops below the minimum safe operating level, and to renew power when a safe operating level returns.

The excess stack temperature switch (see fig. 2-3) breaks power to the burner whenever the stack temperature exceeds the control setting, and renews power when the stack temperature drops back to normal operating range.

Beside the two automatic controls spoken of as part of the control assembly of a vertical fire tube boiler, there is an automatic control to protect against flame failure, and an automatic draft regulator.

Flame failure protection consists in a safety combustion control which ensures shutdown if ignition or flame fails. This shutdown will occur within 30 seconds for the 250,000 Btu boilers, and within 4 seconds for the 595,000 Btu boilers.

After a safety shutdown, a manual reset is necessary for all these automatic controls, including steam pressure and low water cutoff controls.

Optimum draft for the boiler unit is automatically maintained by a barometric draft regulator, which is preset at the factory. To make sure that the draft regulator functions as intended, take care to install it correctly in the sheetmetal tee provided for it.

HORIZONTAL FIRE TUBE BOILERS

The horizontal boiler used at advanced bases is a 30-hp 125-psi boiler fired by light oil, and equipped with fully automatic controls. Figure 2-4 shows a horizontal boiler equipped with oil burner. All operating mechanisms and controls are placed within easy view and reach of the operator, and there is easy access to the boiler for servicing and repairs.

Burners

The oil burners are integral with the boilers. The components include a motor driven fuel oil pump, pressure atomizing equipment, direct electric ignition, pressure indicating gage, and strainers to ensure delivery of clean oil to the burners.

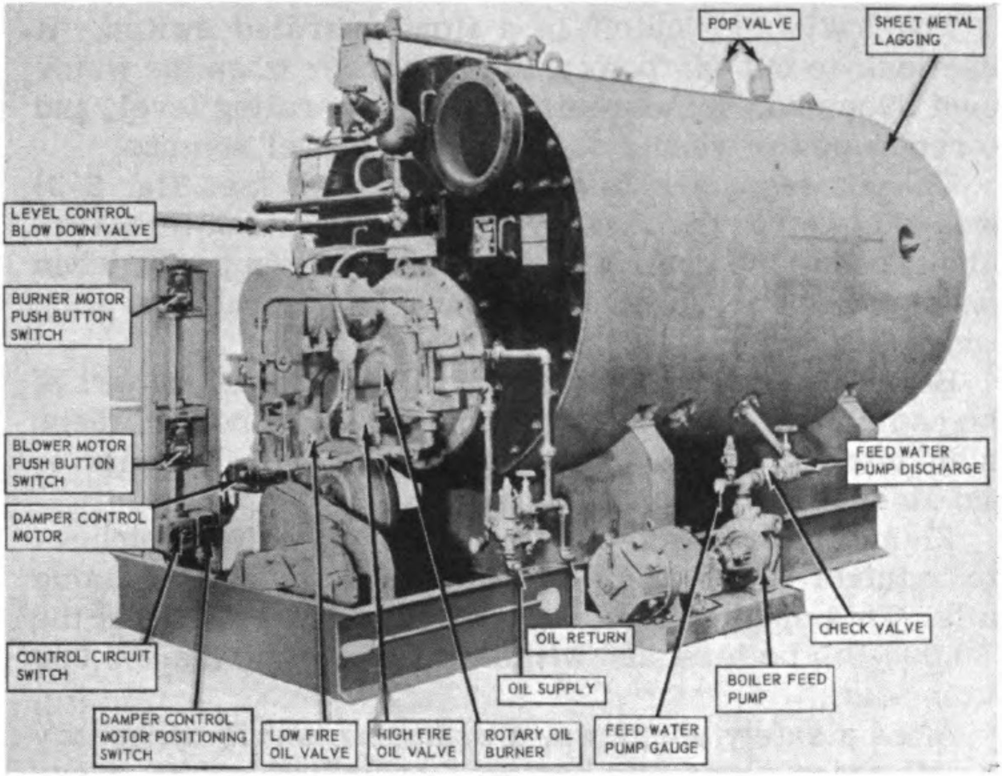


Figure 2-4.—Horizontal boiler, powered by a 220-volt 60-cycle 3-phase motor.

All piping, fittings, and valves necessary to safe and efficient operation are part of the boiler component. Valves include an oil metering valve, pressure regulating valve, and automatic pressure relief valves. These latter are installed on the discharge line of the fuel oil pump, and wherever else they may be required to prevent excessive pressure to the burner.

The main fuel valves are solenoid valves of the dual type, installed in series and wired in parallel. If one valve fails to close on boiler shutdown, the other valve will take over and ensure closure.

Drum

The furnace is located within the drum, but far enough from the drum shell so that there cannot be unequal heating of the shell surface. The boiler water circulates freely around the furnace. The cylindrical drum is large enough so that there is little risk of serious fluctuation in the water level. Easy access to the watersides is

provided by manhole and handholes; however, the cover and yoke assemblies of these openings must be absolutely watertight and steamtight when the boiler is in operation.

The drum is equipped with the necessary components to allow for feedwater entrance, and for the escape of steam. The connections include feed nozzles, and connections for the water column, injector, and blowoff; steam outlet nozzle; and safety valves. Steam pressure regulators, mounted on the drum, are of the Bourdon tube or the bellows type. A fuller discussion of how these pressure instruments work is given in the later section, Gages. An electric relay system connects the steam pressure control with burner and draft fan controls.

Fire Tubes

Tubes must be maintained so that they are watertight and gastight. They are arranged around the furnace so as to provide for maximum heat transfer, but are spaced so that there will be no interference with water circulation in the drum, nor with the cleaning and flushing of the watersides. It is important that these tubes be in perfect alignment.

Controls

By virtue of its electric relay connection with burner and draft fan controls, the steam pressure regulator maintains steam pressure within prescribed limits, and for all loads within the rated capacity of the boiler. The burner and draft fan controls provide for the rate of combustion, or of furnace heat release, that is demanded by the pressure regulator. All the combustion controls on these horizontal boilers provide for full on-full off automatic control.

Draft fans have an interlocking device with the burner control circuit that prevents burner operation (in fact, prevents the entry of fuel, and prevents ignition) until air volume required to sustain combustion has been established. However, a switch is provided so that hand operation of draft fans is possible when the boiler must be purged after flame failure, or prior to a cold start.

The flame failure control devices operate to close the fuel valves and to shut down the burner equipment within 4 seconds after a flame failure; they also actuate an alarm. These devices are electronic, and while they readily detect flame (both pilot and main flame) under all firing conditions, they will not be actuated by hot refractory or any other heated body.

Flame failure can also occur in the primary lighting off processes. If the pilot flame is not properly established and confirmed within a brief period, this is a species of flame failure. The controls on this type of boiler will cause a safety shutdown if the pilot flame is not confirmed within 15 seconds after the ignition system has been energized. When these safety shutdown controls have operated to cut off fuel and ignition, a manual reset is necessary before operation can be resumed.

The water level regulator and low water cutoff is either mounted on, or cross-connected with, the water column. The feeder has a switch which automatically starts or stops the feed pump, and so controls the water level in the drum. The low water cutoff is wired into the burner circuit, and not only effects a safety shutdown when water drops to minimum safe level, but also sounds an alarm. Here again, manual reset is required before operations can be resumed.

Condensate Return System

A condensate return system is provided with the horizontal fire tube boilers only if it is specifically requested. The unit consists of a feed pump, a receiver tank, and all the necessary piping connections and fittings.

The feed pump must have the capacity to deliver TWICE the total quantity of water required by the boiler at maximum load and maximum pressure. Suction strainer, check valve, and shutoff valve are part of the pump unit.

It is possible to have a second feedwater pump and motor, identical to the first, in place of the injector. The pumps can then be used alternatively by means of a double throw switch.

The capacity of the receiving tank is at least one-fifth the volume evaporated by the boiler, steaming at full load capacity, in a 1-hour period. Fittings and connections in

the tank include water level gage (or gages), makeup valves, drain cock, thermometer, and connections to pump suction, vent, overflow, and condensate return. One makeup valve is an automatic float-operated valve, the other is hand controlled. Two water level gages are installed on vertical tanks; these gages overlap, but give a water column that is almost double the length of that given by one gage. The thermometer is mounted on the outside of the receiver tank, and indicates the average temperature of the water in the tank.

GAGES

Among the most important of the boiler fittings are the water gages, pressure gages, and temperature gages. To ensure safe and efficient operating levels, all auxiliaries and all instruments in the boiler room must be watched carefully, but this is especially true of gages.

Water

Boilers are equipped with water gage glasses and a series of trycocks.

The three trycocks, mounted one above the other, provide a means for checking water level when the boiler is in operation. The upper trycock should release steam; the center trycock, steam or water, or both; and the lower trycock, water only.

A light placed behind the water gage will make it easier for you to check the water level in the gage. Use of a corrugated (REFLEX) glass also facilitates checking the water level, since the portion of glass covered with water appears darker than the rest. The importance of constantly checking the water level will be apparent later on, when you study the section on high water and low water control.

Pressure

Pressure gages are installed so that connections lead from the top of the pressure line, if possible. Connecting lines must be given support, to prevent vibration being

transferred to the gage. A steam pressure gage is connected to the highest point in the steam drum.

A gage pressure reading of ZERO means that the pressure recorded is atmospheric pressure only. A gage pressure reading of 5 would indicate 5 lb per square inch (psi) above atmospheric pressure, or an absolute pressure of 19.7 psi. Figure 2-5 will show you what is meant by absolute pressure (psia), gage pressure (psig), and the relationship between them. A figure followed only by the abbreviation "psi" represents gage pressure.

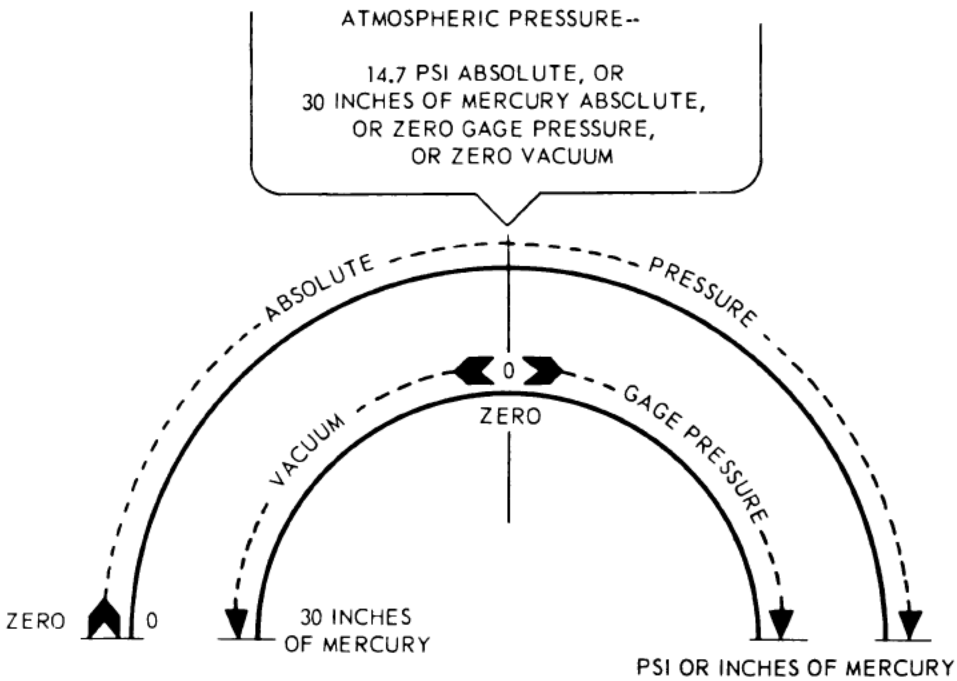


Figure 2-5.—Relationships between vacuum, atmospheric pressure, gage pressure, and absolute pressure.

The Navy makes extensive use of the Bourdon tube type of gage for measuring boiler steam pressure. These Bourdon tube gages are especially good for measuring high pressures. The instrument consists of a bronze tube, threaded into a socket, and fitted with dials made of plastic or of steel. Figure 2-6 illustrates the working parts of a Bourdon tube pressure gage. The position of the pointer end represents the balance (or unbalance) between two forces: (1) the coiling tendency of the metal walls of the tube, and (2) the steam pressure entering the tube, and tending to straighten it out.

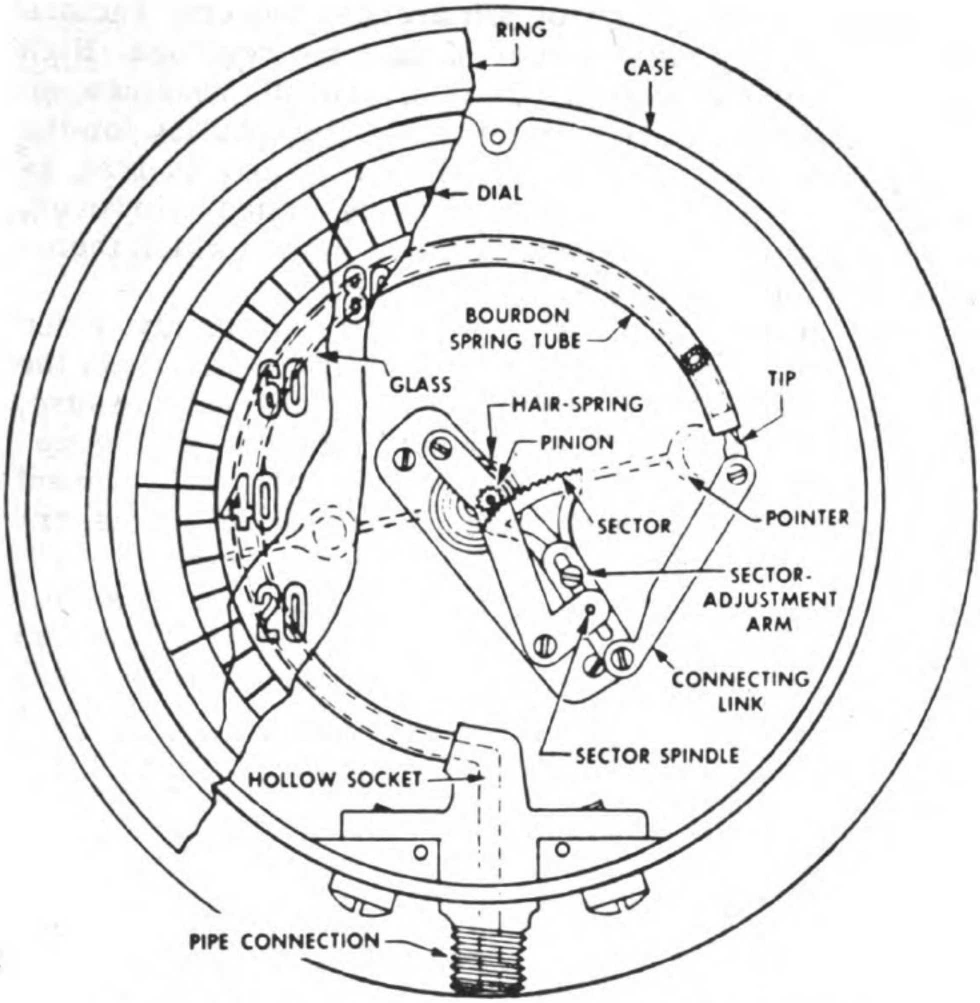


Figure 2-6.—Typical single-spring Bourdon tube gage.

The socket end is screwed into an opening in the boiler system. As steam enters the tube, the pressure forces it to straighten out, and the pointer which is connected to the closed end by a system of levers and gears begins to rotate along a calibrated dial. As pressure drops, the free end tends to coil up, and the pointer reverses direction.

These gages are usually mounted on a wall panel. To ensure a flat mounting surface, you can insert washers under the flange of the gage case. Secure mounting is necessary, to prevent vibration. Another method of preventing mechanical vibration is to use flexible tubing as the final length in the connection between piping and gage; this also eliminates the danger of piping strain on the gage.

Vibration and piping strain are not the only factors that will destroy the accuracy of the gage readings. High temperatures can also result in inaccurate readings, so consider temperature when choosing the location for the gage. Also install gages at points that are as free as possible from moisture or corrosive fumes. However, many gages come in phenol plastic cases, which themselves are corrosion and rust resistant.

Never open a gage cock or valve too quickly, since sudden applications of pressure can rupture or strain the Bourdon tube. Avoid any sudden release of pressure, since this has the same detrimental effect as sudden application. The installation of a relief valve will prevent overpressure. This valve should be set for a pressure well within the pressure range of the gage itself.

It is best never to oil gage movements or linkages, since the advantages of lubrication are offset by the fact that the oil may attract dirt, and form gummy substances that will cause sluggish or inaccurate action of the gage parts. Replace broken glasses immediately, before dirt can penetrate to the bearings and the movement mechanism.

These boilers are provided with tappings for safety valves. Into the tapping, first screw a nipple, then a 90-degree elbow. The safety valve can then be screwed into the elbow, with the valve outlet facing outward. Set the safety valve to operate at a gage pressure specified by the bureau or the activity concerned.

For measuring low pressures, manometers are the most satisfactory type of gage. The manometer is a U-shaped tube, partly filled with liquid. One arm of the tube is open to the atmosphere, the other is connected to the system or space in which pressure is to be measured. When pressure in this space is greater than air pressure, the liquid is forced upward in the arm open to air pressure. If air pressure is the greater, the liquid rises in the arm connected to the pressure line or chamber. The amount of pressure is read from a calibrated scale paralleling the arms.

Temperature

Temperature gages are necessary to good operation of a steam plant, since at times you may need to observe

or record the temperatures of feedwater, fuel oil, lube oil, and various other fluids.

The liquid-in-glass thermometer, very similar to the type in common household use, will be employed wherever it is suitable for the temperature range involved. They can be protected by armor, or by being partially enclosed in a metal case.

FUEL SYSTEMS

The most important features of the fuel oil system for your boiler are the burner and atomizer components, since it is here that the fuel is prepared for combustion. Unless the correct fuel-air mixture is obtained, you will get accumulations of soot or of explosive gases in the smokestack, possible warping of metal surfaces, and other difficulties which will detract from efficiency of operation.

Preheaters are needed on some boilers in order to heat the oil to specified ignition temperature, at low boiler loads; boilers fired by heavy oil require preheaters, but since the fire tube boilers described here are light oil (or coal) fired, you probably will not need this equipment.

Beside the necessity of feeding the proper mixture of air and fuel to the burner, and of having the fuel oil at a temperature that will ensure good ignition and combustion, there is also the necessity of keeping the oil free from water or sediment.

Contamination of Fuel Oil

Leaks in oil tanks may lead to a contamination of the fuel oil, and this in turn will lead to unsatisfactory operation of the boiler. In a later section of this chapter, Fuel Oil Testing, you will learn how to determine the presence and the amount of water and sediment in a sample of oil. A very simple but practical device is to install a test petcock at the bottom of the fuel tank. When a sample from the petcock indicates water contamination, draw off the water (which will have sunk to the bottom of the tank), and then use the oil with caution.

On an installation that has settling tanks, watch for water in the bottom of the gage glasses on the tanks. If there are no settling tanks, a special drain line can be run from the bottom of the service tank to the booster pump. Suction on this line will show whether or not there is water in the bottom of the tank.

Sputtering of the atomizers is an indication that the fuel oil has become contaminated with water. You should immediately take suction from another tank, to prevent loss of oil suction by the suction pumps.

Loss of Oil Suction

Contamination of the fuel oil is not the only cause of loss of suction. If the oil level in the tank feeding the service pump falls to the level of the suction, a mixture of air and oil will be fed to the atomizers. Here, again, the atomizers will sputter excessively, and you should immediately shift the suction to another tank.

Suction may be lost because of the action of some improperly trained man. Where several valve wheels are located close together, he may open or close the wrong valve. Another common mistake is to take suction from a tank which has an inadequate supply. The best method of preventing mistakes of this sort is to see that your operating personnel are thoroughly trained. If suction is lost, no matter what the reason, they should promptly start the standby pumps. In your own mind, try to rehearse all the possible ways in which suction loss can occur, and then instruct your men in the best method of meeting any such emergency, should it occur.

For example, you can lose suction if the oil has not been heated to a point where it will have the required fluidity. Attempting to obtain oil from distant tanks can be another cause. Suction can be lost in the service tank if heavy residue oil has settled to a height above the high suction; the best remedy for this situation is to take low suction on the tank.

Mention has been made of the accidental closing (or opening) of a wrong valve. You can see that if the spring-loaded master control valve in the fuel oil line to the burners should accidentally be closed, suction would be lost.

The best remedy would be to immediately close the boiler stop, so as to hold as high a steam pressure as possible in the boiler. When oil suction has been restored, relight the burners. Then, when steam pressure is within a few pounds of operating pressure, open the boiler stop and resume operation.

Coal and Gas Burners

Since the boilers with which the Utilities Man normally works are the packaged boilers already described, you will probably work almost entirely with oil-fired boilers, and may require very little information concerning those that are fired with either coal or gas. However, in the event that you should sometime have to operate such a boiler, this section will be of help to you.

Coal-fired furnaces may be fired manually, through the use of stationary grates, shaking grates, or hand stokers. Other types are fired mechanically, by stokers or by pulverization.

Hand-fired furnaces may be either the updraft or the downdraft type. The former is more commonly used, because the downdraft type has been found unsuitable for high rates of firing. The updraft type has a single grate, which supports the fuel and admits the air needed for combustion. Downdraft furnaces have two grates; the upper grate admits the air, and receives the coal. The incandescent fuel then falls to the lower grate, where it completes the combustion of volatile matter given off by the coal.

Mechanical stokers have advantages over hand-fired furnaces. They permit the use of cheaper grades of fuel, while at the same time they maintain better furnace conditions, increase efficiency and capacity, and reduce the amount of labor required.

Underfeed stokers have the fresh fuel supplied below the burning zone. Overfeed stokers have the fresh coal fed to the fuel bed from above. Chain-grate stokers have grates connected to an endless traveling chain driven from the front end of the stoker. Spreader stokers combine hand and pulverized coal-firing methods.

Gas as a fuel requires careful handling, since it mixes easily with air, and burns readily. A leak of gas into an

unlit furnace, or into the boiler spaces, could be extremely dangerous. Most gas-burning equipment is provided with automatic combustion controls and automatic safety devices, to ensure proper combustion conditions and safe operation.

BOILER OPERATION

Instructions for operating an oil-fired boiler are given in NavPers 10656-C. A few additional warnings about cutting in and operating boilers will help you to do a better job of training men in the Utilities Man service ratings.

Lighting Off

Make sure that all scale, oil, and foreign matter have been removed from the boiler, and that gaskets are in good condition. Vent the boiler to permit the escape of air, and be especially careful to veniilate the furnace, for at least 5 minutes, with a forced draft fan. Gas in a furnace can cause a serious explosion when the furnace is lighted off.

Inspect the fuel supply in the tank and the feedwater level and temperature, and make certain that all safety valves are operating properly. Blowdown valves, feed valves, and trycocks also should be checked, and auxiliary equipment such as pumps, fans, motors, and controls.

Establishing the Flame

After opening the damper which regulates the burner air supply, set the steam pressure controls, open the valves in the fuel line, and then close the power entrance switch. The flame should be established and detected by the photo cell, permitting the burner to automatically continue in operation. If the flame flutters or fails, the pump may be airbound, or there may be leakage in the fuel line.

After the flame has been established, adjust the air damper, water feed controls, and excess stack temperature switch.

Low Water Control

When you fill the boiler, have it cool, but have the boiler water hot, if possible. Open the valves at the gage glass, and open the topmost trycock, so that any air present can escape. When the water level in the glass reaches 3-5/8 in., close valves and trycock.

Maintenance of proper water level is a major duty in the boiler spaces. If control fails, steam pressure will drop as the immersed surface area of tubes is reduced; even more serious is the fact that the exposed metal surfaces may warp and distort. Any distortion of the heating surfaces may cause damage to brickwork, serious steam and water leaks, and even boiler explosion.

Low water may also be the result of feed pump failure, a leak in the feed line, a defective check valve or cutout valve, or a plugged gage glass. If the feedwater is too low in the tank, low water level can result. Whatever the defect, it should be promptly tracked down and corrected.

You can check the low water control by partially draining the boiler. When the water level drops to the point where only 1 in. of water shows in the gage glass, the control should react, opening the switch in the main control circuit. The burners will then instantly shut down. When boiler water level is restored to normal, the control contacts close, and the unit restarts.

If the boiler is manually operated, and a low water casualty occurs, take the following steps:

1. Turn the master or quick-closing valve that will shut off the fuel supply to all burners.
2. Close the feedwater valve.
3. Secure the steam stop valve.
4. Slowly lift the safety valve by hand, so as to gradually relieve boiler pressure.

If this procedure is carefully followed, the boiler will cool off gradually, and this slow cooling will be, in effect, an annealing process applied to the overheated portions. In this way, the danger to boiler pressure parts will be minimized. NEVER try to remedy a low water casualty by increasing the feedwater supply to the boiler.

Securing the Boiler

After the atomizers have been extinguished, remove them as soon as possible from the burners, to prevent carbonization of the fuel remaining in the atomizer tips. When the furnace has been cleared of gases, close it tightly, to prevent the entrance of cool air while the furnace is still hot.

BOILER MAINTENANCE

No boiler can give long-term satisfactory service without adequate maintenance of both waterside and fireside, and frequent checking of gages and valves. Responsibility for this maintenance—either the actual performance, or the instruction and supervision of service ratings—is one of the duties of the Utilities Man First Class and the Chief Utilities Man.

Correct maintenance is the best insurance that a boiler will operate at maximum efficiency. Regular maintenance procedures should include a daily surface blowdown, to get rid of scum or other accumulations on the water surface, and a daily bottom blowdown. In using the bottom blowdown valves, never allow the water in the gage glass to fall out of sight.

The water gage also should be given a blowdown, to ensure removal of sludge and sediment that might cause control failure. A check should be made on the trycocks of the water gage, to make sure that they are ready for emergency use. Blowers and other accessories should be checked regularly.

Before undertaking any visual inspection of waterside or of fireside, proceed as follows:

1. Cool and drain the boilers.
2. Remove manhole and handhole plates; have spare gaskets on hand.
3. Hose out the internal surfaces of the boiler.
4. Remove ashes from the grates and surfaces of a coal-fired boiler, and clean thoroughly.
5. Remove steam pressure gage for testing.

Watersides

In fire tube boilers, watersides should be checked every three months. After the boiler cools down, drain

it completely, remove handhole and manhole plates, and wash out the boiler with a high pressure stream of water. Do not neglect the line into the boiler, but remove the plug from the cross connection below the water column, and clean out the line.

Inspect the heating surface for corrosion, pitting, and scale. Any severe pitting or scaling indicates that the boiler water treatment is not satisfactory. Gaskets around the manholes may need replacing. Check the valves, to see if there is need to regrind valve seats or repack stems.

When all maintenance work has been completed on the waterside, refill the boiler and add the necessary boiler compound. Dissolved oxygen can be driven off by slow warming up of the boilers.

Firesides

Although boiler efficiency depends largely upon the proper maintenance of the fireside, a semiannual overhaul is usually sufficient to keep operation up to standard. Open the rear cover plate of the boiler, and cleanout plate on front. Cover the motor and controls, to protect them against dust.

Flush out the waterside with a high pressure hose, and then inspect tube sheet and headers for scale. The condition of the tubes at the first cleaning of a new boiler will usually provide you with some idea of how often they will need to be cleaned. Before you begin work on the tubes, take out and clean the stack switch. Do not replace it until after the tubes have been cleaned.

Brush out the tubes with a flue brush. An accumulation of soot will act as insulation, preventing heat transfer from tubes to the surrounding water.

Stack temperature can provide a good check on whether or not tubes need cleaning. Low steam production is also a check, since it is a definite indication of the need for cleaning the tubes.

To clean burners, disassemble the burner head, removing the nozzles. It may be necessary to do this once a month. Separate the strainer and the core from each nozzle tip, and wipe off strainers, tips, and cores with a soft cloth that has been dampened with oil or kerosene. Never use a metal device for cleaning the parts of a nozzle.

Dirty electrodes or porcelains should be removed from their mountings, and cleaned with a cloth dampened with ammonia. Porcelains that show cracks or fissures must be replaced.

If you have been experiencing difficulty with burners becoming extinguished accidentally, the cause may be: (1) a mixture of oil and water is coming from the oil tanks, or from leaky heaters; (2) the burner is choked by solid matter, either because the oil is carbonizing, or the strainers are not operating properly; or (3) air is entrapped in the fuel line, between fuel oil pump and atomizers.

Whenever a burner is choked, remove it at once, and clean it carefully. Make sure that you do not roughen or enlarge the outlet holes, nor alter their shape. Never leave a disconnected atomizer in the burner assembly.

Control Systems

Maintenance of the electrical control system requires little more than keeping the parts dust-free, and replacing them when they become inoperative. Use an air jet to clean electrical parts, hard-finish paper for contacts.

The electronic program relay is a sealed unit which should never be tampered with, except for cleaning the contacts and replacing a vacuum tube. First, open the switch, so that there will be no danger from live parts. Then draw hard-finish paper between the contacts, holding them closed. Occasionally remove photo cells and wipe them clean. When photo cells and vacuum tubes fail to function properly, replace them in accordance with manufacturers' instructions.

On the Cleaver-Brooks fire tube boiler, a type that is used at many Seabee installations, there are two major electrical control systems. One is the electrical control on the feedwater pump, the other is the electrical control assembly on the burner system.

FEEDWATER PUMP CONTROLS not only control the supply of water to the boiler, but operate to prevent a low water casualty.

The pump starter is a magnetic contactor type, with overload relays, and an under-voltage release. It operates either by a switch, or by a manually operated push-button.

If switch-operated, the switch is connected to a float. A drop in float level closes the contact; this starts the feed pump motor, to restore water level. When the float again reaches its normal level, the contact opens and the feed pump stops.

The pushbutton provides a means of manual control for starting the boiler feed pump, independent of water level pump control. If the toggle switch on the pump control housing is in the OFF position, then you must use the pushbutton to start the pump.

The low water cutoff switch is in the same casing with the pump switch. If closing the contact (and starting the pump) fails to restore the water level, the float will continue to drop, and will open this low water cutoff switch contact. In turn, this opens the main control circuit, and cuts out the burner.

DO NOT try to adjust the low water cutoff switch. DO NOT change the setting of the adjusting screw on the water level pump control.

ELECTRICAL CONTROLS ON THE BURNER SYSTEM consist primarily of a motor starter, an ignition transformer, a toggle switch, the Pressuretrol, the pyrostat, a solenoid oil valve, and the Protectorelay.

A magnetic contact is used for starting the motor, with the control circuit actuated by the relay in the Protectorelay. The spark for igniting the fuel is provided by the ignition transformer, energized by the Protectorelay. When the oil has been ignited, the Protectorelay and the pyrostat cut out the transformer.

The pyrostat is a flame failure control, functioning when the oil fails to ignite, or when the flame fails subsequent to successful ignition. The pyrostat is mounted on the boiler front head plate, and has the operating element protruding into the flue outlet. Thus the rise in stack temperature that follows oil ignition closes two contact points. The closed contact energizes the Protectorelay to cut off the ignition transformer spark.

When flame failure occurs, the pyrostat contacts open; this in turn opens the circuit to the burner motor, and the circuit to the solenoid oil valve. Burner shutdown should follow immediately.

This solenoid oil valve is energized as soon as the automatic control starts the burner assembly. When this

valve is open, it allows oil to feed to the burner nozzles; any type of burner shutdown will deenergize the solenoid oil valve circuit, with the result that the valve will close.

The Protectorelay is, of course, the very heart of the burner control system. When the Pressuretrol calls for burner operation, the Protectorelay starts the motor that drives blower and fuel pump, opens the solenoid oil valve, and actuates the ignition transformer to provide the ignition spark. In addition, it is interlocked with low water cutoff switch circuit, so that the opening of the latter circuit will cause the whole Protectorelay assembly to cut out.

In general, boiler control devices differ for different types of boilers, since each manufacturer is likely to incorporate a slightly different type of control systems. The only safe way of learning how these controls operate is to study the instruction manual supplied by the manufacturer with each type of boiler.

Testing and Calibrating Pressure Gages

Maintenance of external fittings in general is simplified by the fact that you can readily and frequently check on their performance. Electrical controls and contacts should be checked, and cleaned or replaced, about once a month. Pressure gages and water gages should be observed during boiler operation, so that you will be aware of maintenance and repair needs as they develop. The performance of safety valve and blowdown valve must also be watched constantly; but as long as their operation is adequate, no attempt at adjustment should be made.

Gages are delicate instruments, and require care and attention. They are most important to the safe operation of any boiler; they tell you what you need to know about water, heat, and pressure conditions, and eliminate guesswork.

Proper care of gages should include the following:

1. Keeping the dials and face clean.

2. Having the gages well lighted, to facilitate taking the correct reading.

3. Keeping covers tight, and replacing broken glass promptlv.

4. Protecting the gages as far as possible from vibration, excessive temperatures, corrosive liquids, and rapid fluctuations in pressure.

Whenever you have reason to believe that a gage is not accurate, you should test it with a dead-weight tester. Figure 2-7 illustrates such a test.

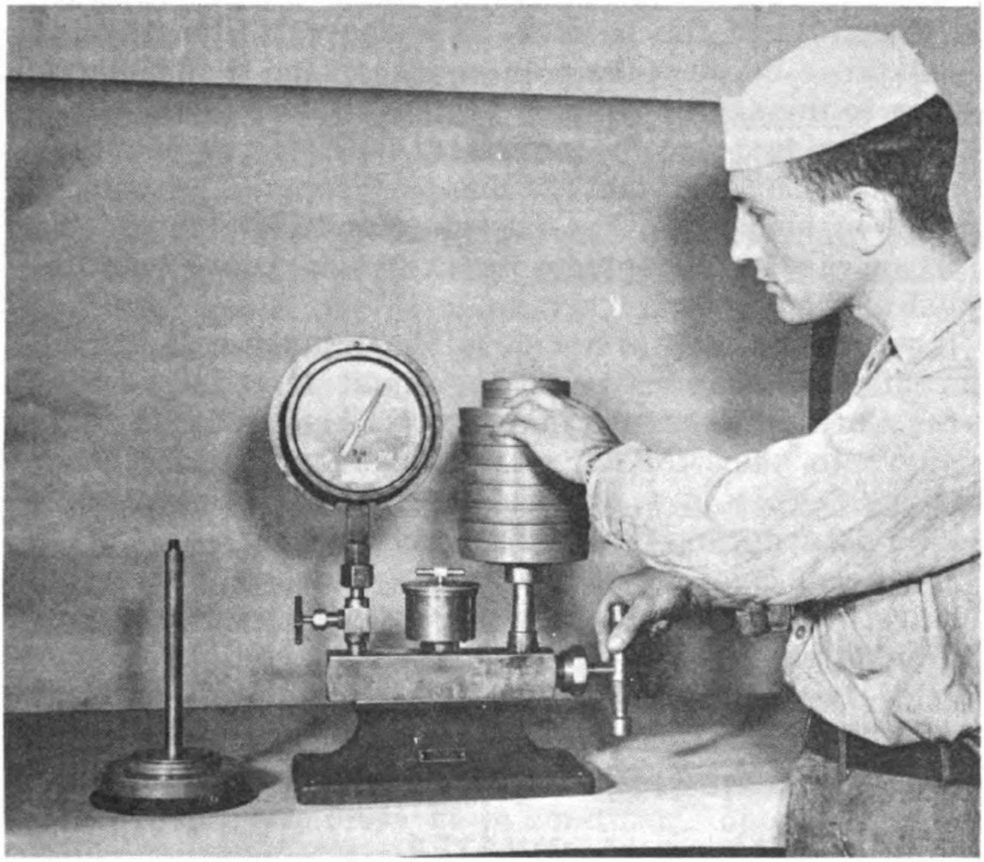


Figure 2-7.—Testing a pressure gage.

To make such a test, connect the gage to the testing apparatus, as illustrated. If the tester is not the type that remains filled with oil at all times, you will have to fill it for the test. Then level the tester, insert the plunger in the cylinder, and note the reading that you get on the gage. Ordinarily, a plunger without any weights attached will apply a pressure of 5 psi.

Weights come in increments of 5, 10, and 20 pounds per square inch. Add weights in increments as desired and gently rotate the plunger to overcome the frictional resistance between the plunger and the cylinder wall. If the gage reading increases in increments equal to the

weights added, the gage is in adjustment. If not, adjustments will have to be made to the gage.

If you find that the pointer of a gage travels too far, or not far enough, as each weight is added, you must correct the fault. This is accomplished by altering the leverage to change the ratio of movement between the tube and the pointer. The movement of the sector gear, and therefore of the pointer, is reduced by lengthening the distance between the pointer pinion and the link connection to the sector gear.

You may find that the increment increase or decrease is correct, but that the reading is wrong. The pointer must then be reset. The sector gear must engage the pinion on the pointer spindle for somewhat more than full travel of the pointer.

If you find that it is not possible to make a gage read correctly over the entire scale, adjust it so the reading at the working pressure is correct. Also, make a table or curve to show the correction to be applied for other readings. This is a calibration table or curve and is used in determining the correct readings.

When you have finished the test, remove the weights one or two at a time. Remove the gage and drain any remaining oil from it. If the gage is in need of replacement of any parts, be careful not to bend or distort any parts while you are renewing them. When finished with the replacement job, recalibrate the gage.

FEEDWATER

Unless you make certain that the quality of boiler feedwater meets certain requirements, a careful maintenance of the system of tanks, pumps, and feed pipes will not in itself ensure against operational difficulties.

In your study of chapter 8, of this training manual, you will learn of the purification processes that must be applied to water to ensure that it is fit for human consumption. Boiler feedwater must often be given chemical treatment before it can be used in steam plants. This chemical treatment not only prevents (or at least reduces) the formation of scale and corrosion, thus prolonging the life of the boiler, but it also effects an appreciable savings in fuel.

Serious difficulties may be experienced with feedwater systems because of improper functioning of the feed pump, a feed pressure that is too high or too low, too much or too little water, valves that stick because of dirt or scale deposits, or because of overtightening of the stem packing, and similar defects. Pumps and valves, although for the most part dependable, are subject to mechanical failure. The correction of such conditions is a part of boiler maintenance, however; and you will find that practically all troubles that you experience in connection with feedwater can be resolved by treating it with the prescribed chemicals.

If your boiler is equipped with a condensate return, this will greatly reduce the need for water treatment. However, you ought to maintain a slight alkalinity with soda ash or similar compound.

TREATMENT

For low pressure steam boilers constructed of steel, use soda ash or caustic soda to combat corrosion. When any scale formation is present, use the soda in combination with metaphosphate and tannin.

In small boiler plants, chemicals are admitted at the feedwater inlet of the pump. Where maximum-capacity tanks are installed for condensate returns, you can admit the chemicals directly to the tanks; in such a case, the boiler feed pump must be in continuous operation during the period when the chemical is added.

Whether dispersed through an improvised feeding device, or introduced through a chemical feed pump, the compound must never be added in the dry state. Unless it is first mixed with water, and then fed in solution form, any treatment chemical will soon plug the chemical feed lines.

Idle boilers, no less than those in operation, may require feedwater treatment for corrosion. This treatment will vary somewhat, according to whether the boiler has been taken out of service for a standby period or for an extended period.

For standby periods, fill the boiler completely with water of high alkalinity; pH should be at least 12 (causticity of about 200 ppm), and sulfite residual at least 100

ppm. You can obtain this result by using 1 oz caustic soda, and 3 ozs sodium sulfite, per 100 lbs boiler water content.

From time to time, sample and test the water, to make sure that these residuals are being maintained. Once a month, make a test on pH and sulfite residual. If you find these are low, add caustic soda and sodium sulfite. Recirculate the water for a short time, to ensure a uniform distribution of the chemicals. Do not allow the water level to drop, since the boiler must be kept completely filled.

A boiler that is to remain idle for an extended period must be laid up dry. Clean the boiler thoroughly and heat it enough to drive off all moisture. Then place trays of quicklime inside the boiler. The amount of quicklime should be in the proportion of 20 lbs for every 100 boiler horsepower.

After putting in the quicklime, close the boiler tightly, to prevent the entrance of moisture, and also to prevent fluctuations in air pressure. Examine the boiler from time to time; when the quicklime has become saturated, replace it, and reheat and close the boiler.

Another method (the wet method) requires that you clean the boiler as thoroughly as possible by mechanical means. Then fill it with water brought through the hot water heater. Use a ratio of 20 lbs caustic soda, and 1 lb tannin, to every 1000 lbs water. Build a light fire to bring this mixture to a boil, so as to bring about the desired chemical changes. Then close all vents and seal the boiler.

New boilers must be given an initial water treatment, to remove foreign matter and oil that may be present in the water and steam spaces. The same treatment may also be used for boilers that have become fouled with grease or scale.

Dissolve 5 lbs of caustic soda and 1-1/2 lbs of sodium nitrate, or 10 lbs of trisodium phosphate, for each 1000 gals of water that the boiler holds at steaming level. Put this mixture into the boiler. For multiple drum boilers, you can divide the charge, putting equal amounts into each of the lower drums.

Fill the boiler with hot feedwater to the level of the bottom of the steam drum. Turn steam into the boiler

through the boiling-out connections, or the bottom blow, and let the boiler gradually fill, up to the level of the top of the gage glass. Keep boiler steam pressure somewhere between 5 and 10 psi, and continue the boiling out for 48 hours.

Immediately after boiling out, give a series of bottom blows to remove the bulk of the sludge. The boiler should then be cooled, washed out thoroughly, and then given the usual mechanical cleaning.

Testing

Low pressure boilers are generally used where the load is limited to the production of hot water, or to the heating of relatively small spaces. In these low pressure boilers, practically all the condensate is returned to the feedwater supply source, so that only a small amount of makeup water is ever required.

FUEL OIL TESTING

Periodic tests on fuels should be considered a necessary part of keeping the whole plant on a satisfactory operating basis.

Most fuel oil analyses are laboratory conducted. Oil tankers, also, have testing equipment. It is doubtful, therefore, if the Utilities Man will have to make these tests, since provision is made for them before the fuel oil reaches the installation. However, it will certainly be helpful to him to know the meaning of various terms used in connection with fuel oil.

FLASH POINT: the lowest temperature at which oil will give off a vapor that will ignite spontaneously when combined with air. Determination is made by means of the closed cup flash point tester.

FIRE POINT: the temperature at which oil gives off sufficient vapor to remain ignited after flashing. Determination is made by means of the open cup tester.

POUR POINT: the temperature at which oil congeals as it cools. Test for it by slowly cooling the oil, and noting the temperature at which it ceases to pour.

CALORIFIC VALUE: the amount of heat, expressed in Btu's, that is generated when oil is completely burned.

ASH CONTENT: the incombustible constituents of the oil. Determination is made by burning an oil sample in a closed container.

VISCOSITY: the measure of internal resistance to flow. The test is made with a viscosimeter, and the results expressed as Seconds Saybolt Furol (SSF).

SPECIFIC GRAVITY: ratio of weight of a given volume of a substance to the weight of an equal volume of water, at the same temperature and pressure. The test is made with a hydrometer.

CENTRIFUGE: device for determining the percentage of impurities (water and sediment) present in the oil.

Flash Point

If at any time you should test for the flash point of an oil sample, remember that the temperature is that at which a slight explosion occurs, and not the temperature at which a small bluish halo is visible around the test flame. The halo is not a reliable indication, so always wait for the slight explosion.

Burn Point

The burn point is another term for fire point, and indicates the temperature at which the oil will continue to burn after it has been ignited. Burn point depends, however, not only on temperature, but on the viscosity of the oil.

Viscosity

By the definition given before, viscosity represents the amount of resistance to flow. With a raise in temperature, there is a lowering of viscosity. Most viscous oils, therefore, are heated somewhat before being pumped. However, caution must be exercised to keep temperatures in tanks and at pumps limited to a range of 90 to 100 F. With very heavy oils, the temperature may be allowed to go as high as, but no higher than, 120 F.

Sediment

An accumulation of sediment anywhere in a system can detract considerably from efficiency of operation.

Testing for sediment is one test that you may find it necessary to make. The testing is done by centrifuging a mixture of the oil and benzole.

Two centrifuge tubes must be used. Each should contain 50 milliliters of 90-percent benzole, and 50 milliliters of the oil to be tested. The tubes should then be tightly stoppered, and immersed and agitated in a 120 F water bath. The water must come up to the 100 milliliter mark.

After at least 10 minutes in the water bath, the tubes should be put in the centrifuge, and whirled for 10 minutes. Then the volume of water and sediment is read from each tube. They are then centrifuged for a second 10-minute period, and the readings of water and sediment taken. This procedure should be continued until identical readings of water and sediment have been obtained from each tube, and for three times in succession.

Illustrations of testing equipment, and descriptions of testing procedures, are given in *Engineering, Operation and Maintenance,* NavPers 10813-A (pp. 50-52).

HYDROSTATIC TESTING

A hydrostatic test indicates whether the various parts are tight enough to eliminate the danger of leakage. This test, therefore, is advisable when a general inspection is to be made for leakage; and it is NECESSARY upon the completion of a general overhaul, or of repairs to pressure parts.

The pressure at which the test is made should always be greater than the expected operating pressures, in order to allow a margin for safety. Usually, the hydrostatic tests are made at boiler design pressure, or perhaps at 1-1/4 boiler design pressure. The pressure applied on a 5-year test is 1-1/2 times design pressure.

Wash out the boiler in preparation for the test, using a hose for washing the steam drum, and the tubes and headers. Then remove all loose scale and foreign matter.

After cleaning all gaskets and handholes, replace the handhole and manhole plates. Gag the safety valve; a handtight gag is sufficient, since you might bend the valve stem if you set up too tight. Then close all connections on the boiler, except air cock, water gage, pressure gage,

and the valves through which water pressure is to be applied. You can now fill the boiler with water (up to the top of the steam drum); after all air has been expelled, close the air cock, and apply the water pressure, increasing it slowly.

During the application of the water pressure, keep a careful watch upon the gage, and check the boiler itself for any sign of deformation. Since changes in the temperature of the boiler water can cause pressure changes, keep the water at approximately the same temperature (between 75 and 80 F is a good temperature range) throughout the test. There is bound to be some drop in pressure, but it should not be more than 1.5 percent over a 4-hour period.

There are three possible results of a hydrostatic test: you may find that the results indicate that the boiler is in satisfactory operating condition; you may find that weak parts deform under the pressure applied; or you may find evidence of serious leakage.

If deformation is evident, but it is not feasible to close down the boiler for extensive repairs, run a second hydrostatic test, stopping at a point less than the pressure at which deformation occurred. If this test indicates safe working conditions, set your new working pressure for the boiler at two-thirds of the test pressure, and reset the safety valve accordingly.

Where excessive leakage is shown to occur at tube joints, it will be necessary to reroll the leaky tubes. Where pressure loss is very high, but only a nominal leakage occurs at tube joints, drum seats, and gaskets, the leakage is through valves or fittings, and these must be inspected and overhauled as necessary. Where plates leak badly, it may be caused by poor seating of the gaskets. Sometimes a gasket will get caught on the outer edge, between the plate and the counterbore. Hitting the outside of the plate a light blow with a hand hammer may relieve tension on the gasket, and cause it to seat properly.

After a hydrostatic test has been completed, the fitness of the boiler for use is not finally determined until the safety valve has been tested and set.

SAFETY PRECAUTIONS

Boilers are provided with controls and safety devices to reduce danger to personnel as far as possible. But there is always the possibility of some unexpected situation, in which the continued operation of the equipment, and the safety of the operating personnel, may be threatened. For this reason, everyone working on a boiler should train himself to safety thinking, and safety action.

The section, Boiler Safety, in chapter 13 of NavPers 10656-C, has a very practical set of rules, summarized as things that you should never do, and things that you should always do. Most of these elementary precautions should be second nature to a man by the time he is ready to advance to the general rating.

When repairs must be made, the boiler is secured, and line switches opened to ensure that there will be no risk of personnel receiving shocks from electrical contacts. All opened switches should be tagged, and the HOLD-OFF cards should indicate by whose orders these circuits are open. Not until the same person has authorized it should the tags be removed, and the switches closed.

You must never enter a boiler, for inspection or repair work, with a naked light. A hand flashlight is usually the best thing to employ; but if you need a portable light of higher power, you should use one that is on a lead. In such a case, you must be sure that the electric lead is properly insulated; and you should provide a wire or a rubber guard for the light globe. Naturally, you should never, as a foreman, send a lower-rated man into a boiler without making sure that he is aware of the need for these precautions.

Never send anyone into a boiler without first making certain that the air is safe. Station another man outside, to render help in case of accident or emergency. Before anyone is allowed to enter dead boiler drums, furnaces, ashpits, and so forth, make sure that (1) all connecting valves are closed and tagged, (2) the temperature is not dangerously high, and (3) the boiler is sufficiently ventilated.

When the repair work has been completed, make sure that all tools, waste, and gear are out of the boiler, before a test is started.

The best safety precaution is preventive maintenance. Frequent inspections will disclose whether or not soot, scale, dust, or oil has collected on heating surfaces. As long as inspections show that a boiler is in practicable operating condition, there is usually no cause to worry about any immediate boiler casualty.

In spite of the most careful attention to safety, however, there may arise situations that threaten the efficiency of operation, and the welfare of personnel. Three common sources of danger are steam leaks, flarebacks, and oil leakage.

Steam Leaks

Gaskets may blow from different causes. The wear and tear of long use is the most common cause, but they may also fail because they were not evenly set when they were installed.

Flarebacks

A flareback may result when a sudden drop of air pressure occurs in a boiler, or it can be caused by the explosion of oil vapor and air (or gas and air) in the furnace or in the uptake. Drop in pressure may occur when the forced draft blower is slowed up or stopped. Explosions of oil vapor or other gases indicate poor atomization.

Most flarebacks occur when a boiler is being lighted off, or when an attempt is being made to relight a burner from a hot brick wall. In lighting off with no power available for operating the blower, personnel should exercise special caution. As far as possible, they should always stand clear of the probable path of a flareback.

To reduce the danger of flarebacks, boiler personnel should observe these precautions:

1. Keep atomizer valves tight at all times, to prevent leakage of oil into the furnace.

2. Before lighting a furnace, wipe up any oil accumulations.

3. If atomizers should accidentally be extinguished, immediately shut off the oil, and blow through the furnace with air before relighting.

If the flareback causes a fire, or damages the boiler, take such other measures as sound judgment indicates, in order to localize the casualty, and remedy it.

Oil Fires

Any place where oil may collect by leakage from the oil burner system is a potential source of fire.

Fuel oil in bulk is not capable of spontaneous combustion, nor will it easily catch fire. However, once an oil fire gets a start, it does not take long for it to reach serious proportions. Every Utilities Man should know how to handle an oil fire promptly and efficiently.

Fire-fighting equipment is usually available, and ready for use; it is equally important that you, and the men under your supervision, know how to use it. For example, a blanket of chemical foam or of CO_2 is the most effective means of smothering an oil fire, but there may be times when water will have to be used. In such a case, apply the water under pressure, and through a spray nozzle; this will be the best way to get the smothering effect. The spray will also cool the hot surfaces in contact with the oil, and will thus prevent re-ignition.

If your clothing, or that of some one else, catches fire, NEVER run, nor remain in the draft of the blowers; either of these courses would only fan the flames. Try to remove the clothing, or else to smother the flames with rags or other clothing. If there is nothing at hand to use, smother the flames by rolling on the floor or ground.

SUPERVISORY RESPONSIBILITIES

The responsibilities of the Utilities Man First Class, and particularly of the Chief Utilities Man, are especially important in the operating of a boiler for heating and hot water purposes. The safety of the personnel present, and the protection of the equipment, are involved here, as well as the efficient functioning of the boiler.

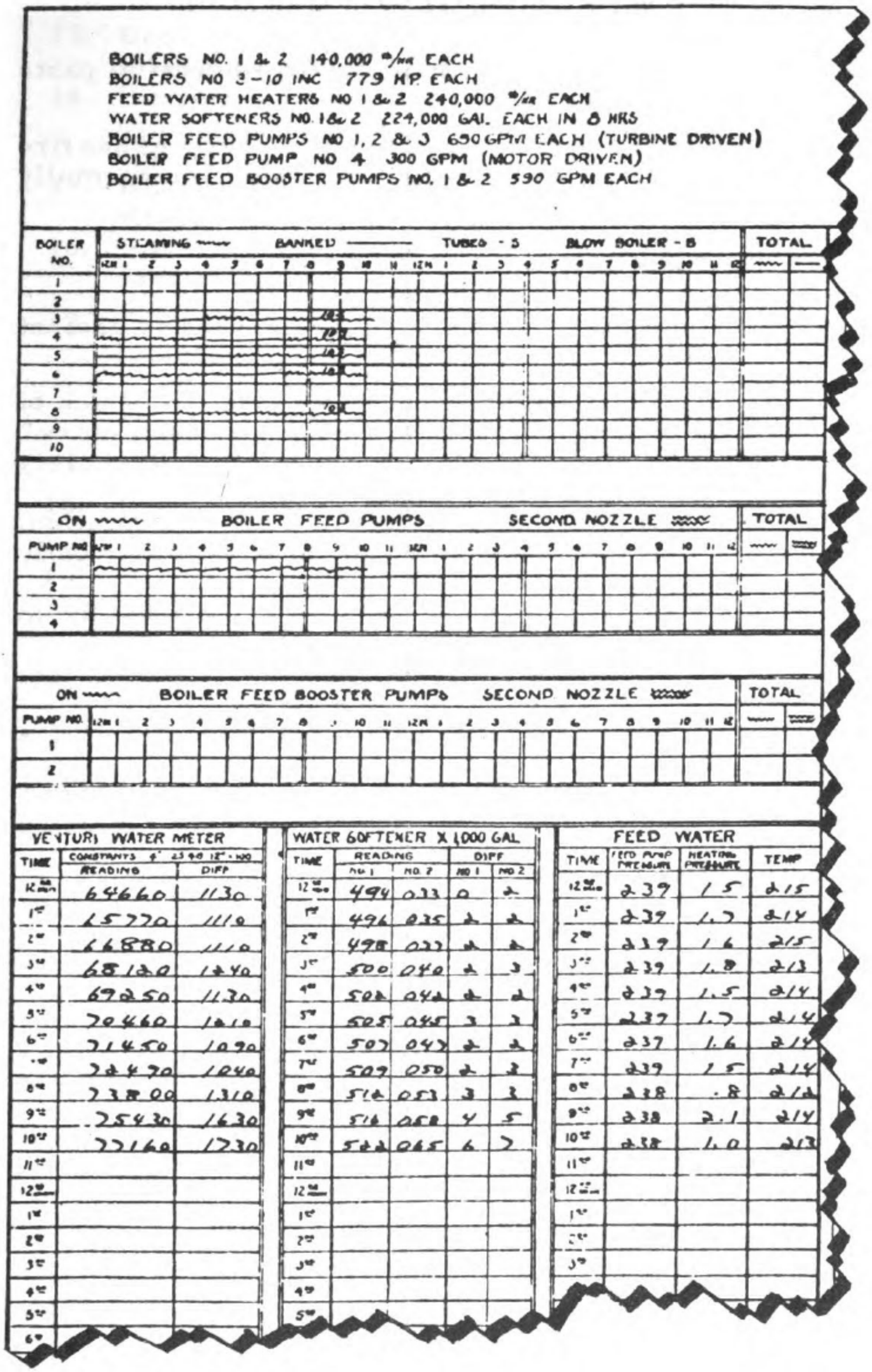
You will have to be aware of the many things that could go wrong, in the absence of proper care and oversight, with fuel supply, burner assemblies, feedwater supply, steam control, and many other factors. You will have to train the men in the Utilities Man service ratings, so that they are equally aware of the consequences of negligence, or of following incorrect procedures. And you will have to supervise them carefully, until you are certain that they completely understand and follow your instructions.

An operating record should be kept on all boilers. Figure 2-8 shows part of such a log sheet, and gives some idea of the type of information required, and the way in which it should be recorded. Other sections of the log may show such additional factors as fuel consumption, feedwater consumption, boiler, feed pump, gage readings, and tests on valves. Each daily log should also indicate what breakdowns occurred, or what repairs were made.

The man on duty is responsible for making these entries in the log. You are responsible for impressing him with the necessity for regular and accurate recording of the required information.

You should make frequent inspections of buildings, to see that all spaces are heated as required. You should also check your boiler accessories, to see that they are in good operating condition.

At stated intervals, reports on condition of boilers must be submitted on the forms furnished by the Bureau of Yards and Docks. These reports, which may be required annually, semiannually, or even quarterly, require the listing of boiler capacity, operating pressures, safety valve settings, general condition of the boiler, and similar data. The records and reports that you and the men under your supervision have maintained regularly will be a great help to you in the preparation of the reports required by BuDocks.



BOILERS NO. 1 & 2 140,000 #/HR EACH
BOILERS NO 3 – 10 INC 779 HP EACH
FEED WATER HEATERS NO 1 & 2 240,000 #/HR EACH
WATER SOFTENERS NO. 1 & 2 224,000 GAL. EACH IN 8 HRS
BOILER FEED PUMPS NO 1, 2 & 3 650 GPM EACH (TURBINE DRIVEN)
BOILER FEED PUMP NO 4 300 GPM (MOTOR DRIVEN)
BOILER FEED BOOSTER PUMPS NO. 1 & 2 590 GPM EACH

BOILER NO. — STEAMING — BANKED — TUBES - S — BLOW BOILER - B — TOTAL

BOILER FEED PUMPS — ON — SECOND NOZZLE — TOTAL

BOILER FEED BOOSTER PUMPS — ON — SECOND NOZZLE — TOTAL

VENTURI WATER METER (CONSTANTS 4" 2540 12" - 100)

TIME	READING	DIFF
12	64660	1130
1	65770	1110
2	66880	1110
3	68120	1240
4	69250	1130
5	70460	1210
6	71450	1090
7	72490	1040
8	73800	1310
9	75430	1630
10	77160	1730
11		
12		
1		
2		
3		
4		
5		
6		

WATER SOFTENER X 1000 GAL

TIME	READING NO 1	READING NO 2	DIFF NO 1	DIFF NO 2
12	494	033	0	2
1	496	035	2	2
2	498	037	2	2
3	500	040	2	3
4	502	042	2	2
5	505	045	3	3
6	507	047	2	2
7	509	050	2	3
8	512	053	3	3
9	516	058	4	5
10	522	065	6	7
11				
12				
1				
2				
3				
4				
5				

FEED WATER

TIME	FEED PUMP PRESSURE	HEATING PRESSURE	TEMP
12	239	1.5	215
1	239	1.7	214
2	239	1.6	215
3	239	1.8	213
4	239	1.5	214
5	237	1.7	214
6	237	1.6	214
7	239	1.5	214
8	238	.8	212
9	238	2.1	214
10	238	1.0	213
11			
12			
1			
2			
3			

Figure 2-8.—Boiler log.

QUIZ

1. According to the text, what are the 3 essential parts of any type of boiler?
2. In setting heat release limits on an advance base fire tube boiler, the only factor over which you normally have control is the
   (a) type of grate
   (b) type of firing
   (c) nature of the refractory
   (d) amount of boiler surface exposed to radiant heat
3. When a 150 psi boiler is put into operation, which of the following precautions will always be necessary?
   (a) Make sure that the grate is positioned securely on its supporting ring.
   (b) Make sure that all burners are in operation.
   (c) See that the burner flame is symmetrically distributed.
   (d) See that the heating surface is actually in contact with the flame.
4. Why are dual solenoid valves used as the main fuel valves on a horizontal fire tube boiler?
5. What 2 advantages result from the installing of a large drum in a horizontal fire tube boiler?
6. What use is made of the 3 trycocks on a water gage?
7. A steam pressure gage reading of zero indicates what pressure in the system?
8. For measuring high pressures in a boiler, the type of instrument most frequently used is a
   (a) pyrometer
   (b) manometer
   (c) Bourdon tube gage
   (d) diaphragm gage
9. Why is it so necessary to get a correct fuel-air mixture?
10. When sputtering of an atomizer occurs, what procedure should you follow?
11. Name 6 ways, mentioned in the text, in which oil suction may be inadvertently lost while a boiler is in operation.
12. The type of hand-fired coal burning furnace most suitable for high rates of firing is the
    (a) updraft type
    (b) downdraft type
    (c) stationary grate type
    (d) double grate type

13. Before lighting off a furnace, why should you run the forced draft fan for at least 5 minutes?
14. If a low water casualty is allowed to occur, what will be the probable result, in addition to loss of steam pressure?
15. What are the 5 possible causes of a low water casualty, as listed in the text?
16. Why should you remove the atomizers as soon as possible after securing a furnace?
17. The strainers and cores of a nozzle tip should be cleaned with a
    (a) cloth dampened with kerosene
    (b) cloth dampened with ammonia
    (c) fine emery
    (d) hard-finish paper
18. What are the 3 causes, as listed in the text, for accidental extinguishment of a burner?
19. The electrical controls and contacts on a boiler should be inspected and cleaned at least once each
    (a) day
    (b) week
    (c) fortnight
    (d) month
20. Whenever you have reason to doubt the accuracy of a gage, you should
    (a) return it to the manufacturer
    (b) replace it with a new one from stock
    (c) test it with a dead weight tester
    (d) report it to the cognizant bureau
21. If it is not possible to make a gage read correctly for its entire scale, you should
    (a) prepare a calibration curve for all readings
    (b) reset the pointer, so that it will travel farther as each weight is added
    (c) increase the linkage connection to the sector gear
    (d) adjust for correct readings at working pressure, and prepare a calibration curve for other readings
22. What are the 2 major benefits derived from the chemical treatment given boiler feedwater?
23. The need for feedwater treatment is greatly reduced when the boiler is
    (a) a low pressure boiler constructed of steel
    (b) equipped with a condensate return system
    (c) not equipped with a condensate return system
    (d) a high pressure boiler constructed of steel

24. Why is it sometimes necessary to treat the feed-water in idle boilers?
25. Why should new boilers be given an initial water treatment?
26. Where are most fuel oil analyses made?
27. What is meant by the fire point, or burn point, of fuel oil?
28. In the testing of fuel oil, a centrifuge is used for determining
    (a) calorific value
    (b) percentage of impurities
    (c) percentage of ash content
    (d) specific gravity
29. The safe temperature range, in tanks and at pumps, for most viscous oils is
    (a) 50-65 F
    (b) 65-80 F
    (c) 80-90 F
    (d) 90-100 F
30. Testing for sediment in oil is done by centrifuging a mixture of
    (a) 90 ml of benzole and 50 ml of the oil
    (b) 50 ml of 90-percent benzole and 50 ml of the oil
    (c) 90 ml of 50-percent benzole and 50 ml of the oil
    (d) 50 ml of benzole and 90 ml of the oil
31. The pressure at which a hydrostatic test of a boiler is made usually is
    (a) less than design pressure
    (b) the same as design pressure
    (c) the same as operating pressure
    (d) three times operating pressure
32. How do you make sure of the fitness of a boiler for use, after a hydrostatic test has been completed?
33. For inspection or repair work within a boiler, what type of light is safest?
34. What is the probable cause if a recently replaced gasket blows?
35. Why should you never attempt to relight a burner from a hot brick wall?

CHAPTER 3

PUMPS

Much of the work that is done by the Utilities Man First Class, or the Chief Utilities Man, involves the use of pumps, or the instructing of lower-rated men in their installation, operation, and maintenance. Most of the equipment and the processes described in this training course require some type of pump. For example, pumps are needed to supply feed water to boilers; to circulate coolants and lubricants; to draw condensate out of condensers in refrigeration, air conditioning, and distillation units; to lift water from wells and distribute it throughout a system; and to discharge sewage into settling tanks or mains.

All pumps should be installed, operated, and maintained as indicated in the manufacturer's plan, or the operating manual that accompanies the equipment. With new equipment, operation should be a simple matter, both because the pumps are in first rate operating condition, and because the operating manual provided by the manufacturer gives you the necessary instructions for putting the equipment into service and furnishes you with some guides for dealing with any operating troubles that may arise.

However, every pumping unit that you will operate will not be new, and in some cases the operating manuals will not be available. In this chapter, therefore, you will be given the basic information needed to install, operate, and maintain the classes of pumps that are commonly in use in the Navy.

Before taking up these classes or types of pumps, separately, it will be worth while to consider certain facts that apply generally to all pumping mechanisms.

Pumps vary widely in construction and operating principles. Their driving power may come from gasoline or diesel engine, electricity, steam, or compressed air. The use to which they are put largely decides the type selected. Thus they may be classified according to the mechanical principle of operation (which is the classification employed in this chapter), according to the power drive, or according to the kind of service to which they are put.

Simply defined, any type of pump is a machine which takes suction on a fluid at low pressure, or at low level, and raises it to a higher pressure or level. When the level of the pump is above that of the fluid, the pumping apparatus is usually designed to create a vacuum. Atmospheric pressure on the fluid will then force it to enter the vacuum. When the pump level is below that of the fluid, the pump receives the fluid by gravity flow.

The "power end" of a pump is that end where the steam, electricity, or compressed air is put to work. There must be an inlet for the steam, and an exhaust outlet.

The "water end" of a pump is the part where force is exerted on the fluid. There must be provision for suction (where the liquid enters) and for discharge (where the liquid leaves the pump).

The term "suction head" refers to pressure on the fluid entering the pump. It is usually expressed in terms of feet of water, if positive; in terms of inches of mercury (Hg), if negative.

The term "discharge head" may be used to denote pressure on the liquid leaving the pump, or level of liquid on the discharge side, in respect to the level of the pump.

It is hardly necessary to point out the fact that pumps should be installed on a secure and even base. Vibration transmitted to the working parts will increase maintenance requirements; and if there is a downward slope from suction pipe to pump, an air pocket will form, causing water hammer and a reduced suction.

There are four factors that must be given careful consideration whenever a pump is to be installed. These factors are: location, foundation, alignment, and head.

LOCATION

The location of a pump usually depends upon the general design of the system of which it is a part. However, in any case where you must decide upon its location, you should place it as close as possible to the water or other fluid supply. In this way, you can have a short, direct suction pipe, and a comparatively low suction lift. Ensure that the pump will have adequate protection against snow, rain, seepage, or dust.

Low suction lift is most important, since under ideal conditions no pump can lift water on the suction side more than 34 feet, and in practical situations an even lower limit is necessary. Suction lift for a reciprocating or rotary pump located at sea level should be about 20 feet; for a centrifugal pump, the limit is about 15 feet. Again, if hot water rather than cold, or a fluid with a greater specific gravity than water, is being pumped, the limits of suction lift will be further reduced. Increasing altitude also lessens the effective suction lift.

When feasible, it is best to avoid any suction lift whatever, by installing the pump in a dry well below the level of the water in the intake. If the danger of flooding, or the difficulties of maintenance, make this type of installation undesirable, suction lift can be increased if provisions are made for priming. Alternatively, if vacuum pumps are available, they can be used to exhaust air from the suction lines. With air exhausted, there is practically no atmospheric pressure to prevent the rise of the water.

Accessibility is an important factor in placing a pumping unit. There must be sufficient room for accomplishing inspections and needed maintenance. Allow head room (trap or ceiling opening) if a crane, hoist, or tackle is to be used. Provide flange fittings or unions, placed as close to the pump as possible, in all connecting lines; this will make removal easier. When installing a reciprocating pump, allow room for the removal of rods and pistons, and for repacking or replacement.

FOUNDATION

The foundation for the pump baseplate should be of concrete, with embedded J-bolts. These bolts should

be long enough to allow for shimming. Bolts should be enclosed in a pipe sleeve about two and one-half times the diameter of the bolt, as indicated in figure 3-1.

ALIGNMENT

The alignment of the power and water ends of a large pump will have to be checked after the pump has been mounted on its foundation. In the case of small pumps, these two major parts are aligned and bolted together at the factory, and it is usually necessary only that you handle them carefully, so as not to spring them out of alignment.

To ensure proper leveling of a pump when it is being secured to foundation, you will need a spirit level. If necessary, remove the top casing or bearing cover of the unit, and test the level of the machined surface. Test twice, the second time with the level at right angles to its position when the first test was made.

When the spirit level indicates that the pump level needs correction, use small metal wedges to obtain the desired alignment. Adjust the wedges until the shafts of the pump and the driver are level. Position metal blocks or shims under the parts carrying the most weight, as near to the foundation bolts as possible, and close enough to each other to give uniform support. A gap from 3/4 to 1-1/2 in. should be left between foundation and baseplate, to allow for grouting. If a check of the coupling faces and the

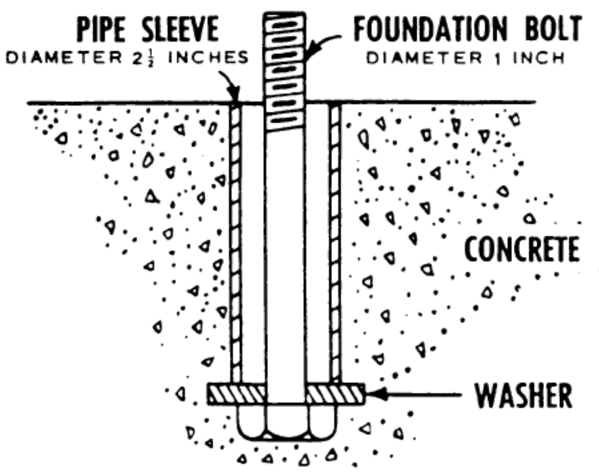


Figure 3-1.—Foundation bolt set in pipe sleeve.

suction and discharge flanges shows that the parts are still out of plumb, adjust the supports until you get the correct alignment.

Figure 3-2 indicates how you should wedge a baseplate to obtain the proper alignment, and figure 3-3 illustrates a unit grouted onto a concrete base.

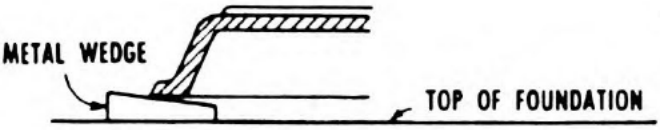


Figure 3-2.—Wedging a baseplate.

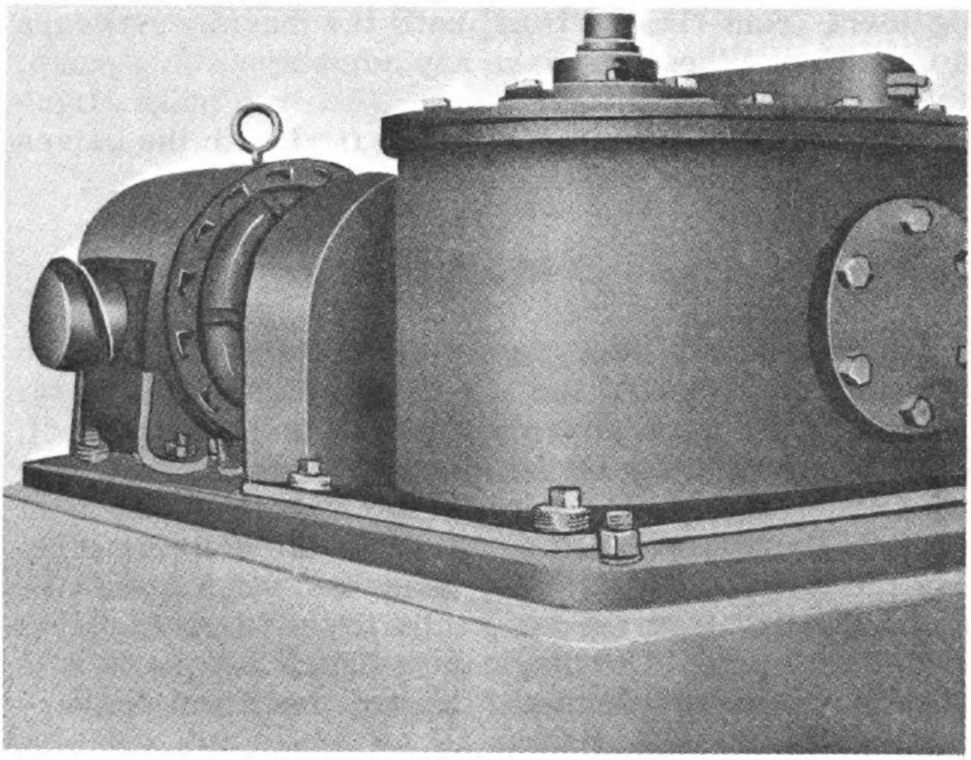


Figure 3-3.—Baseplate of a pump unit grouted to the foundation.

Check the angular alignment between the pump shaf and the drive shaft by using a taper gage, or feeler gage. Take the measurements at 90-degree intervals around the coupling. Adjust the shims under the baseplate, to correct any misalignment; but remember that any adjustment in one direction can cause misalignment in another direction. When the feeler gage shows an identical

measurement at all four points, you can be sure that the pumping unit is in angular alignment.

In connecting the piping, avoid the use of force, and provide piping supports to minimize strain on the pump itself. At least one of these supports should be located close to the pump. After the piping has been connected, take the precaution of checking pump alignment again; if it is satisfactory, reconnect the coupling halves.

At this point, it is a good idea to start the pump, let it thoroughly warm up, and operate it for a short time under normal conditions. Then close it down, and check the alignment of the coupling faces.

When you install a new pump, it is advisable to check alignment from time to time, until the machinery wears into position. When you make any adjustment on a pump, check alignment in all directions. When you make alignment checks of coupling halves, do so first with the halves separated, and then with them connected.

HEAD

The term "head" refers generally to the height to which the pump must raise the water or other fluid. Total static head (or total dynamic head, as it is also called), is usually computed as the vertical distance from the water level in the well or reservoir to the highest point to which the water must be raised in the delivery pipe. When the term "static delivery head" is used, the distance indicated is that from the pump inlet to the highest point in the delivery pipe. The diagram in figure 3-4 illustrates the differences between total dynamic head and delivery head.

The capacity of an individual pump—that is, the number of gallons per minute (gpm) that it can deliver to the required level—depends upon the horsepower and speed of the pump, and the total dynamic head (TDH).

Method of Determining Head

All pumps are provided with nameplates showing horsepower, rpm, discharge, and head. However, there might be some occasion when you would have to determine the

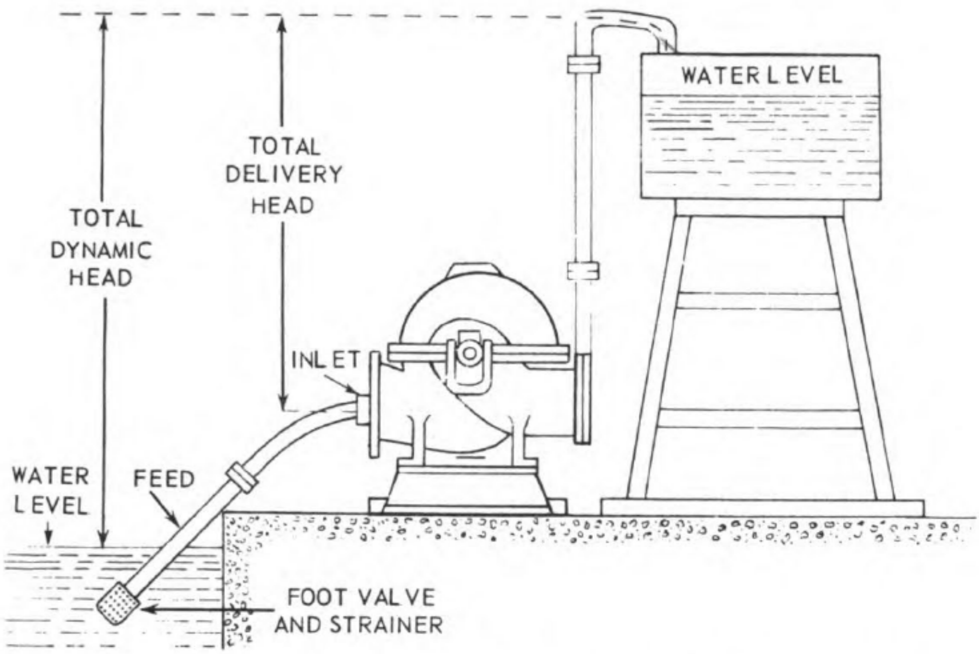


Figure 3-4.—Diagram showing dynamic head and delivery head in a pump.

head from other information. In such a case, the essential data will be:

1. Pressure at suction and discharge, as indicated by pressure gages.

2. Elevation of gages and connecting pipe lines at suction and discharge; take the measurements from a convenient point, such as the centerline of the pump shaft.

3. Velocities in suction and discharge pipes; average velocity in feet per second can be found by dividing discharge in cubic feet per second by the cross-sectional area (square feet) of the pipe.

Denote pressure head, in feet of liquid, as read on the discharge gage, by h_d, and the corresponding data from the suction gage by h_s. (The method of converting pressure reading to equivalent feet of liquid is explained later in this section.) Denote the elevation of the connection to the discharge pipe by z_d, and the elevation of the connection to the suction pipe by z_s. Let V_d and V_s represent, respectively, the velocities in discharge and suction pipes. You can calculate the head from the formula:

$$H = h_d - h_s + z_d - z_s + \frac{(V_d)^2}{2g} - \frac{(V_s)^2}{2g}.$$

The term "g" represents acceleration due to gravity, and is usually taken as 32.2 ft/sec ^{2}. It will simplify your work, and make no significant change in the result of your computation, if you use 64 as the value of $2g$.

Now let us see what other computations you must make in order to determine head. Your gage readings indicate pressure in lb, and you want to convert them to pressure head in feet. A column of water 1 ft in height produces a pressure of about 1/2 lb per square inch; specifically, 0.434 psi. So if you wanted to determine pressure in lb for a vertical pipeline of any given number of feet, you would multiply the number of feet by 0.434. Conversely, since 0.434 lb is the pressure equivalent to a column of liquid 1 ft high, 1 lb is the pressure equivalent of a column of liquid 2.3 ft high (1.000)/0.434. Therefore, by multiplying the gage readings by 2.3, you convert them to pressure head in feet.

In calculating velocities, you need to know cross-sectional area in square feet. The cross-sectional area of a pipe is found by multiplying the square of its radius by 3.1416, or the square of its diameter by 0.7854. For most pipes, nominal diameter is expressed in inches; in place of converting inches to fractional feet and then squaring, you should first make your computation of area on the basis of inches, and then divide this result by 144.

Friction Losses

Actual head in a pump would be less than TDH, since some allowance must be made for losses due to friction in the pipes, fittings, and pump itself. Velocity, viscosity, and density of the fluid being pumped influence the amount of frictional resistance. The internal condition of pipes and fittings is also a factor to be considered, and as pipe grows old in service, and deteriorates, there will be an increasing delivery loss.

Frictional resistance to the flow of water varies approximately as the square of the velocity; therefore, as rate of flow (gpm) through pipe of a specific diameter increases, friction loss will increase.

More friction loss develops at valves, fittings, and bends, because of the turbulence that is created, than

develops in a corresponding linear distance in a straight pipe. It is advisable, therefore, to keep fittings to a minimum, and where they must be used, to select the correct type. For example, a wide-open gate valve adds only a negligible friction loss; but if a globe valve of 3-in. diameter were installed, it would add a friction equivalent to that in an 86-foot length of pipe of the same diameter.

Since pipe bends are a cause of additional friction, have your suction and discharge pipes travel in a straight line as far as possible. When bends are absolutely necessary, give them as wide a radius as possible. The friction in a 1-in. 90-degree elbow is equivalent to the friction in 2.6 ft. of 1-in. pipe.

The larger the diameter of the pipe, the smaller proportionally will be the loss due to friction. At a rate of flow of 200 gpm, friction loss for water passing through a 3-in. ordinary iron pipe will be almost 30 times the friction loss for the same rate of flow through a 6-in. pipe. Or, to consider this from another angle, it would take 6 times that rate of flow to produce the same friction loss in an equivalent length of 6-in. pipe.

Increasing the size of the discharge pipe where it leaves the head is a common device for reducing the loss of head from friction in the piping. To prevent the formation of air pockets, use eccentric reducers in the suction line, as illustrated in figure 3-5. The amount of friction caused by the use of increasers and reducers may safely be ignored.

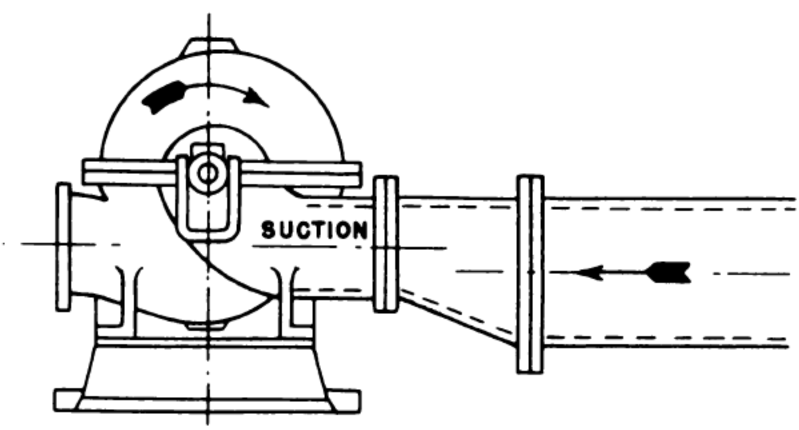


Figure 3-5.—Reduction in a horizontal suction line.

RECIPROCATING PUMPS

The operating principle of a reciprocating pump is a relatively simple one. The essential parts are: a crankshaft, a crank pin, a connecting rod, and a piston or plunger moving in a cylinder. When the crankshaft is revolved, the crank pin also travels in a circular path. The connecting rod, which is joined at one end to the crank pin and at the other to the plunger, transmits this rotary motion as straight line motion, causing the piston to move in and out of the cylinder.

In a direct acting pump, the piston is driven directly by the connecting rod; in an indirect acting pump, the rod drives the piston by means of gears or a flexible coupling.

As the plunger is pulled out of the cylinder, a partial vacuum is created. The suction valve opens, and water rushes into the cylinder. Meanwhile, pressure in the discharge pipe forces the discharge valve to close. When the piston reaches the end of its travel, pressure inside the cylinder is the same as pressure in the suction line, and no more water will enter the cylinder. This is the end of what is known as the suction stroke.

As the plunger starts back into the cylinder, the pressure within the cylinder increases, until it is enough greater than pressure in the discharge line to force open the discharge valve, and force liquid into the discharge pipe.

This type of pump is known as a single acting pump. It discharges water only once during a complete revolution of the crank pin. After this backward, or discharge stroke, there is no discharge while the pump is making the forward or suction stroke. This condition of unsteady flow may cause pressure surges in the discharge line, and possibly in the suction line.

To regulate flow, a double acting pump can be used. Such a pump has two cylinders (see fig. 3-6), one at either end of the plunger. When one cylinder is on the suction stroke, the other cylinder is discharging. In other words, the pump discharges on both the backward and forward strokes (or, if you prefer, the downstroke and the upstroke).

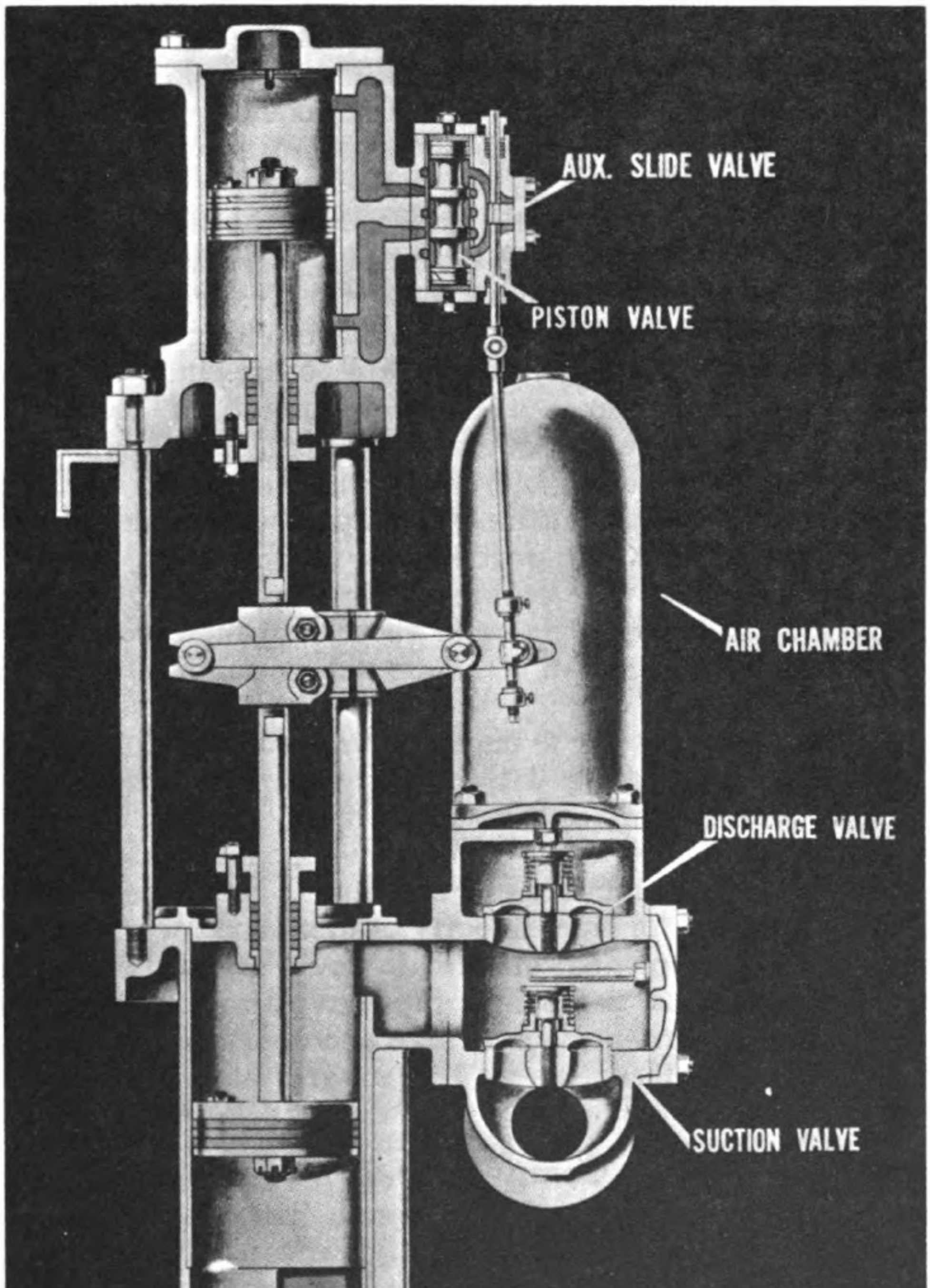


Figure 3-6.—Double acting reciprocating pump.

Even with this improvement, there is a very brief period, at the end of each stroke, when no liquid is moving. By combining two double acting pumps into one unit, with crank pins 90 degrees apart, you get a double acting duplex pump. When one plunger is at the end of a stroke, the other plunger is in the middle of a stroke. With this type of pump, discharge fluctuates about 25 percent from average; with a single cylinder pump, the fluctuation is 100 percent.

The desirability of the duplex over the simplex (single acting or double acting) types of pumps is readily apparent if we look at pump capacities, expressed as discharge gallons per minute. A practical method of determining the capacity of a single acting pump is to take the product of three factors—diameter of plunger in square inches, length of stroke in inches, and number of strokes per minute—and divide the result by 300. (To allow for slip, which is the leakage past valves and plunger, you can deduct 2 or 3 percent.)

The capacity of a double acting pump, capable of discharging water on both the forward and backward strokes, is about twice that of a single acting pump of the same size.

The capacity of a duplex pump composed of two double acting pumps will be very many times that of a single acting pump of the same size.

The efficiency of a pump is the measure of the work that it accomplishes as a machine. For direct acting pumps (plunger driven directly by piston rod) with strokes up to about 10 inches, efficiency would probably be about 60 percent. Larger pumps may have an efficiency of as high as 80 percent, but design and operating conditions must be considered, as well as size.

Component Parts

The cylinder and the plunger so far discussed are the so-called liquid cylinder and liquid piston, by means of which suction and discharge are regulated at the water end of the pump. On a steam-driven reciprocating pump, there is also a steam piston and cylinder unit, which delivers the power for the pump operation.

The steam cylinder is located at the top of the pump, and the piston reciprocates in it, just as the plunger reciprocates in the liquid cylinder. Rings on the steam piston prevent the blowing of steam; the joints on the piston rings are staggered, so that there will be no free path for escaping steam. Drains at the top and bottom of the steam cylinder make it possible to drain condensate from the pump before it is started, and thus prevent water hammer and machinery damage.

Steam from the steam chest enters the cylinders through the steam ports, and a slide valve inside the steam chest controls the path of the steam through the pump. Tappets on the valve rod allow for adjustment of the length of stroke, and valve rod guides prevent the rod from getting out of alignment.

The slide valve actually consists of two valves, main and auxiliary. The main valve distributes the steam, but the auxiliary valve feeds the steam necessary to work the main valve, and its outer edge prevents steam entering the ports at top and bottom of the cylinder. A steam valve gear for a direct acting pump is shown in figure 3-7.

Connection between the steam and the water ends of the pump is made by means of the steam piston rod, which connects the driving end with the driven end. The cross stand, midway between steam and liquid cylinders, operates the valve rod links in conjunction with the piston rod. The semicircular section between steam and liquid cylinders is called the cradle, and serves to keep the cylinders in alignment. On a simplex pump, the cradle is usually referred to as the tie rod.

A plug at the bottom of the liquid cylinder allows for draining the cylinder. Excess air in the system can be bled off through the air cock. The air chamber on the discharge side prevents pounding, and promotes a smoother operation of the pump.

All reciprocating pumps are not steam driven; some are powered directly by an electric motor, and some are belt-driven from a motor or line shaft. However, since this class of pump is essentially a slow speed mechanism, a gear reduction is necessary between motor and pump; for a belt-driven pump, size of pulley for the pump must be calculated on the basis of motor

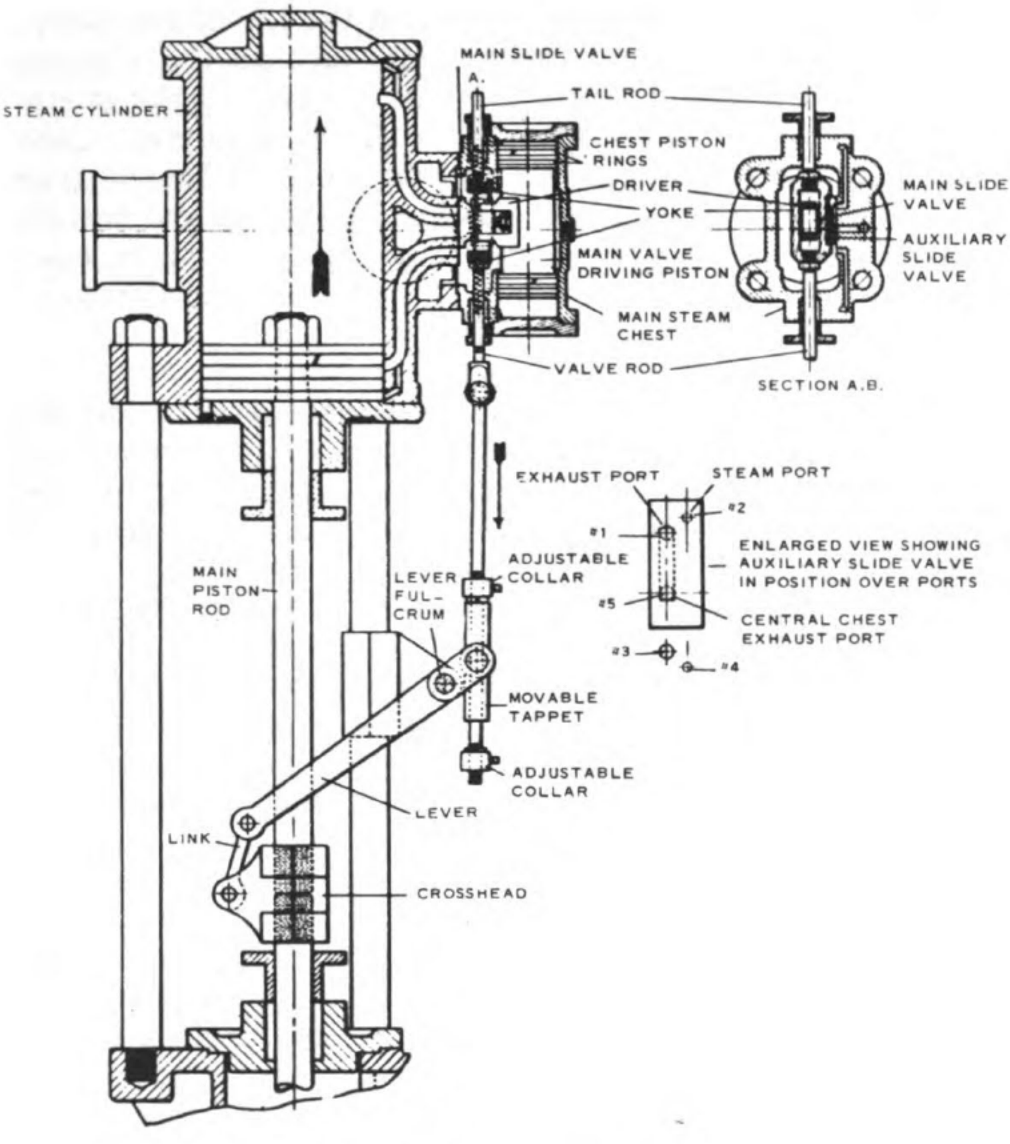


Figure 3-7.—Valve gear.

speed, diameter of motor pulley, and required speed of pump pulley.

Motors and engines operate best under a steady load. A reciprocating pump that has a fluctuating discharge is going to make a pulsating power demand upon its power source. A belt drive will offset this to some extent, but is not always feasible to supply. Gear drive from a motor also means noisy operation, and may necessitate the use of extra heavy shafts and couplings. A secure foundation, and periodic checks on alignment, will certainly be necessary.

Installation

Before putting a pump into operation, make sure that the pump cylinders are in line. Misalignment can result in the scoring of piston rods and cylinder liners, and in extreme cases can cause breaking of followers and bolts.

Clean out steam and water lines, so that no foreign matter remains.

Inspect the packing in the stuffing boxes on the liquid cylinder, the steam cylinder, and the steam chest. This packing is to prevent leakage, and the packing material must be suited to the operating temperatures and other service conditions.

If it is necessary to renew the packing, cut the rings on the diagonal. Fit them carefully to the stuffing box, allowing for some expansion, and position them with the joints staggered, to prevent any free passage for leakage. In tightening the glands, do not set them up too tight, since this will cause unnecessary friction on the rods. The packing will swell at first; after this has happened, the glands can be taken up as necessary. Make sure that the glands do not ride the rods, as they may cause scoring.

Move the steam end valve rods on single piston pumps by hand, making sure that the auxiliary valve moves easily. Remember that the auxiliary valve transmits the steam that actuates the main valve; any sticking of the auxiliary valve will seriously interfere with pump performance.

As mentioned before, you adjust the tappets on the valve rod in order to establish the length of stroke. Reciprocating pumps should run with the full length of stroke as given on the nameplate; this length of stroke has been calculated to ensure that the piston will travel a little beyond the counterbore. You may think that a shorter stroke than the one established will be satisfactory, but this is not the fact. Too short a stroke results in incomplete cushioning, and the formation of shoulders in cylinder and valve chest. When this occurs, you may expect breakage of rings and followers.

In a new installation, you will have to prime the valve chambers and cylinders with liquid. The priming will not have to be repeated if the pump suction line is tight enough so that no air can be drawn in even when

pressure is less than atmospheric. On a pump that operates with a high suction lift, it will be difficult to keep the piping system airtight at high vacuum; the best procedure here will be to arrange a permanent connection for priming.

After installation (or overhaul) of any pump, check carefully to see that all connections and flange bolts have been properly tightened.

Operation

When putting a reciprocating pump into operation, you should proceed as follows:

1. Set up on all grease cups, and oil the pins of the steam valve gear.
2. Open the suction and discharge valves in the water end.
3. Open the cutout valves on exhaust and steam lines.
4. Open the steam line drain valve, and the steam cylinders drains (top, bottom, and steam chest).
5. Open the exhaust valve at the pump.
6. Close the steam line drain valve as soon as all water has drained out of the line.
7. Crack the throttle valve, and then gradually open it to admit steam.
8. Close the steam cylinder drains after the pump has made a few strokes, and the steam cylinder is free of water.
9. Open the throttle valve wide enough to admit sufficient steam to bring the pump up to required speed.
10. Set the cushioning valves so that there will be minimum reduction of pump speed at the end of the stroke, and no pounding in the water end.

If the pump fails to start, there may be steam leakage past the steam piston or valves, and a complete overhaul of the working parts of the steam end may be necessary. However, after you have secured the pump, you should first check for lesser troubles. Look for a closed valve in the discharge or the exhaust line; or for a valve disk that has become detached from the valve stem.

Sometimes the steam piston freezes when a pump has been out of service for a long time. The cause may be excessive friction, or overriding or sticking of the main steam valve.

Operation of the pump should be smooth, relatively silent, and productive of the expected amount of discharge. If the operation is jerky, the chances are that the pump isn't taking suction as it should. Inspect the suction line for obstructions, and make sure that all stop or check valves in the line are open. Check strainer boxes for clogging; check for vapor lock; check the priming; check to see that the piston packing is not too tight.

Erratic operation, as manifested by sticking in the stroke, or stoppage while the throttle is open the proper amount, usually is caused by some defect in the steam end. Small ports and passages in the steam chest may be stopped by an accumulation of scale. Steam may be leaking by the piston rings, or by the main or auxiliary slide valve.

Pounding in the water end may denote improper cushioning, or it may indicate that the air chamber needs to be charged. Groaning in the water end is often due to the fact that packing is too tight; however, it may indicate a misalignment that will result in a scored cylinder or a broken follower.

Pounding in the steam end indicates a loose piston assembly, and the pump should be immediately secured, and the trouble rectified. Groaning in the steam end may indicate the presence of rust, in a pump that has been out of service for some time. It may indicate broken rings, cylinder misalignment, or a steam piston that is cocked on the piston rod. Investigate at once, to determine the cause of the groaning, and to correct the trouble.

If you find that the pump is racing, but without any increase in discharge pressure, look for a leaky piston, for broken or stuck valves in the water end, or for air entering through open or leaky valves in the suction line. Stop the pump as soon as possible, and inspect the most accessible parts first. Leaks by the piston, or throu suction or discharge valves, can radically reduce pump efficiency.

To secure a reciprocating pump, proceed as follows:

1. Close the throttle valve.
2. Close the pump exhaust valve.
3. Open the steam cylinder drains (top and bottom).

4. Close the suction and discharge valves.
5. Close the steam and the exhaust valves.
6. Close the steam cylinder drains (top and bottom), as soon as the cylinder is free of steam.

Maintenance

Perhaps the most important factors in maintenance are guarding against leakage, renewing packing, inspecting for rust and wear, lubricating, and making necessary repairs and replacements.

Leakage may result from worn piston rings, from valves that are not seating properly, or from worn packing. A gland that continues to leak after it has been given a few turns on the nut may need new packing, or it may leak because the throat bushing is too large.

Packing must be chosen for the service. For example, tux (made of fabric and compressed rubber) is used on the liquid end of a pump. The material should be soaked for 24 hours before it is used.

Flax (flax and tallow) is used on the liquid end, and for valves which control liquid flow. It should be used only where cool liquids are being conveyed.

For lines carrying steam or hot liquids, a high pressure packing of asbestos and graphite is best.

An occasional examination of valves for rust and wear should be made. Check the valve seats for wear, and look to see if the springs seat the valves properly. Worn or broken springs, seats, or disks can cause severe water hammer, and a loss in pump capacity.

To prevent rusting of steam valves, remove the valves and valve gear frequently, and clean them with kerosene. When a pump has been out of service for any length of time, give the valves a thin coating of mineral oil before putting the pump back into operation.

Bearings and gears must be lubricated with the proper grade of grease, oil, or graphite. Use a very small amount of cylinder oil on the steam ends of the rods; lubricate outside moving parts with mineral oil; frequently oil the pins of the valve operating gear. However, be careful never to use oil in the steam or water cylinders, or in the steam valve chest.

When a pump is working so poorly that you know it must be in need of repair, check the water end first. Do not touch the steam end until you are quite certain that the trouble is not at the water end. In most cases, pump troubles are due to fouled water cylinders, worn valves, or faulty conditions in water pipe connections outside the pump.

Scoring of the water cylinder does not necessarily warrant reboring or replacing of the liner, unless the scoring is so extensive that the packing rapidly wears out. If the scoring is caught in time, the liner can be smoothed by stoning.

Clearance between the piston and the shoulder is so small that any foreign matter allowed to collect on tapered portion of the rod could prevent the piston from being brought firmly home against the shoulder.

If trouble occurs in the steam cylinder, it will probably be due to wear on the rings, with resulting leakage, or to rings that do not fit the cylinder properly.

To make repairs, drain the steam end, and remove the packing gland and packing. Take off the sheet metal cover, remove the cylinder head nuts, and then lift off the head and take out the piston assemblies.

If the piston rings have excessive clearance, there is no choice but to replace them with new rings.

Take micrometer readings of the cylinder. If these measurements show that the cylinder is out of round, a new liner must be installed. Shoulders present just before the counterbores tell you that the pump has not been making the full designed stroke. Slight shoulders and scoring can be repaired by stoning.

To remove the piston rings, first remove the follower plate for the top ring; before you can take off the bottom ring, you must remove the bull ring. This is the solid ring which has slight shoulders near its inside diameter, to provide for the necessary clearance between top and bottom piston rings.

In reassembling the piston, make sure that the rings have proper gap clearance, and that the ring gaps are staggered. Use a feeler gage to check the side clearances. Replace the assembly in the cylinder, connect the plunger and piston rod in the crosshead, renew gaskets and packing, and put the cylinder in place.

Under conditions of normal operation, the only parts of a pump that will require replacement are the gland packing and valves. Sets of packing, and spare valve disks, should be kept on hand, and replacements made as necessary to ensure a reserve supply. Rarely will you have to order a replacement part for a pump; but if such a situation arises, be sure to include in the order the pump size, figure number, serial number, and so forth, as stamped on the nameplate of the pump.

Safety Precautions

Test all idle pumps daily by jacking them over by hand. Move all pumps by steam or other power drive at least once a week.

Inspect valves every quarter; check the steam valve gear for wear; inspect the liquid end valves; the valve stems, and springs; check the setting of all relief valves.

NEVER USE A JACKING BAR TO START A PUMP WHILE THE STEAM VALVE IS OPEN.

Before you open a steam cylinder or a steam chest, make sure that the drains are opened, and that all steam valves are wired closed and tagged.

Never open the water cylinder or the liquid valve chest of a pump handling liquid at a temperature in excess of 120 F without first making certain that the suction and discharge valves are wired closed, and that the cylinder and valve chest are drained.

CENTRIFUGAL PUMPS

This type of pump operates on the principle of centrifugal force; that is, the force or tendency of a body moving in a circular path to go off on a tangent, along a straight path of motion. In the pump, the liquid is forced to revolve around an "eye", or impeller; in this motion, it builds up an increasing force, until it moves off along a straight line, which in this case is the discharge pipe.

A centrifugal pump must be completely filled with water before it is started. When the pump is put into operation, the impeller, rotating in the pump casing, forces the water from the center into the discharge pipe. A partial vacuum is thus produced at the center. The atmospheric pressure

on the surface of the water source forces water through the suction pipe, to fill this partial vacuum. The impeller rotates it, builds up additional pressure, and discharges it through the discharge pipe. The process is a smooth and continuous one.

There are two major types of centrifugal pumps: volute pumps, in which the rotating impeller is surrounded by a spiral-shaped casing, and guide-vane pumps, in which the liquid being pumped enters the vanes of a diffuser before it is sent through the discharge pipe. Figure 3-8 illustrates these different types.

The volute type is better than the guide-vane pump in cases where the liquid pumped contains grit or suspended matter. Therefore, it is used for irrigation, sewage, and for general purpose pumping.

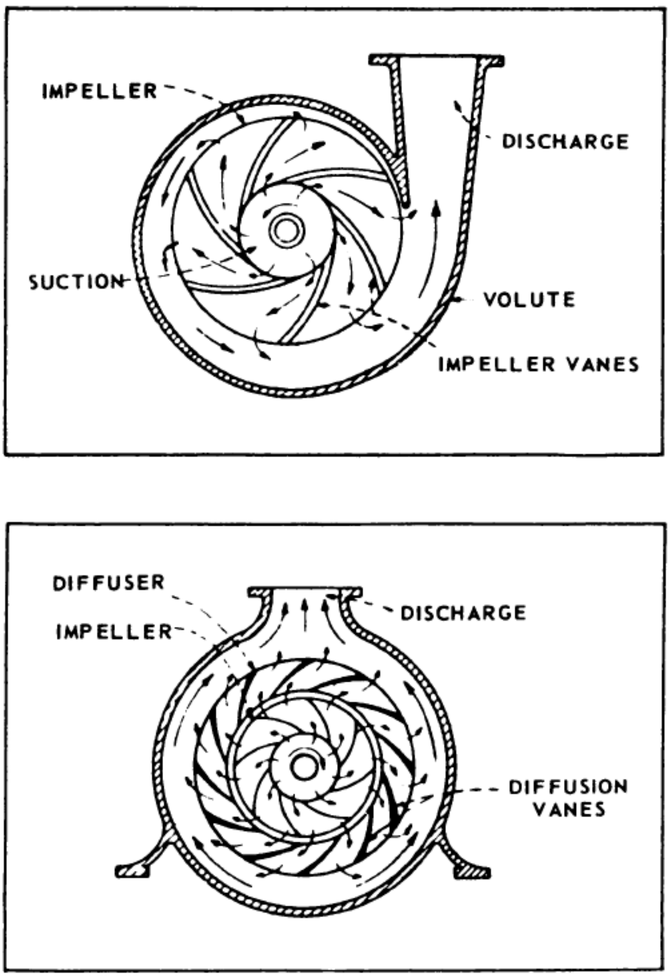


Figure 3-8.—Volute and guide-vane types of centrifugal pump.

The entry passages are designed to bring the liquid into the eye of the impeller with a minimum of disturbance. The impeller blades, fastened to a hub or disk mounted on the shaft, are curved backwards, away from the direction of rotation, to reduce the shock of the swiftly rotating water against the blades.

The guide-vane pump is also known as a turbine pump, because of the similarity of its action to that of a reversed reaction turbine. When total head exceeds 200 ft, the speed of the guide-vane pump becomes too high for satisfactory operation. In such cases, it is customary to adopt multistage pumps or several-stage pumps in series. Figure 3-9 shows the setup of a multistage pump.

When pumps are connected in series in this manner (that is, with the discharge of Pump 1 connected to the suction of Pump 2), the head is equal to the sum of the heads of Pump 1 and Pump 2, but the capacity is that of Pump 1. When pumps are connected in parallel (that is, both suction inlets connected to water source, and both pumps discharging to a single discharge line), the head is the same as that of each individual pump, but the capacity is the sum of the capacities of Pumps 1 and 2.

In general, the volute type is employed where the volume of liquid is large compared to the head, and the guide-vane multistage type is used where head is large in relation to volume. For particular duties, a combination of the two types may be adopted.

Impellers, and diffuser rings also, are subject to severe corrosion. For this reason impellers and shafts are usually made of bronze, monel, gun metal, or similar corrosion-resisting material. The impeller blades are machined and polished, to reduce friction. The use of labyrinth packing rings between impeller and casing will minimize leakage.

The centrifugal pump is essentially a high speed machine, with an rpm of 900, 1200, 1800, or even 3600. The specific speed of a pump is the speed of the impeller discharging 1 gpm of liquid under a 1-ft head. Thus, to change the discharge of a specific pump, it will be necessary to change either the head, or the speed (or both). Since these interrelations are between speed, head, and discharge only, you do not have to worry about pressure

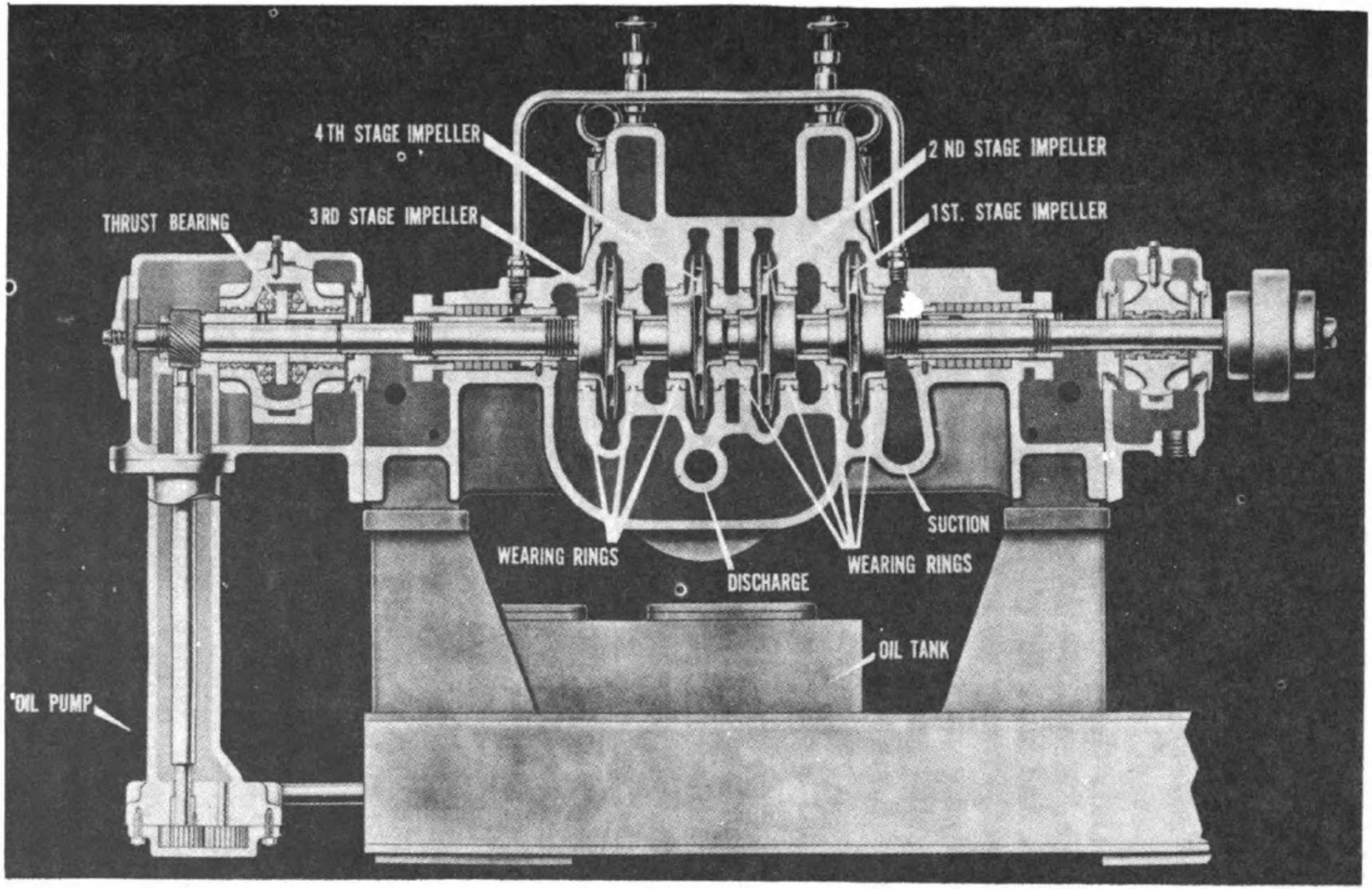


Figure 3-9.—Four-stage centrifugal pump.

surges caused by varying discharge. When a valve in the discharge line reduces or stops flow, the pressure that builds up is limited by the pump design to a value within the strength of piping and other parts. Running the pump against a closed discharge valve, however, can overheat the liquid in the pump.

Installation

Install the pump as close as possible to the water source. Use full-size suction piping, with a minimum of bends, and have the piping slope continuously upward from source to pump, to reduce the possibility of air pockets. Use pipe cement on joints, to prevent leaks. If the suction or discharge piping is to be removed frequently, make the connections to the pump through unions.

The pump may be driven through a steam engine, an internal combustion engine, or an electric motor. The latter is generally considered to be the most satisfactory. If pump and motor operate on the same shaft, both must be mounted on the same rigid foundation, to make sure that the alignment remains true. In making connections between pump and driving mechanism, allow for variations in pump speed without change of motor speed.

Because the driving mechanism is usually more vulnerable to poor operating conditions than is the pump itself, the first consideration in choosing the pump site is its suitability for the driving mechanism.

Priming is necessary each time a pump is to be started, unless the pump is provided with a flooded suction. This can be done by setting the pump on a lower level than that of the water supply. Another method is to have an elevated tank containing about three times the amount of liquid required to fill the suction pipe and pump case. Where steam, water, or compressed air is available for use as a jet, suction lift can be obtained by this ejector priming.

Other methods of inducing suction are: use of a vacuum pump to create a vacuum in the suction line; or use of a small centrifugal or a small rotary pump, to take liquid for priming purposes from the same supply as the large pump will draw upon. Rotary pumps must be stopped as soon as priming is completed, else they will build up

pressures damaging to the pump drive, to gages, and to other accessories.

Except where the pump is primed by gravity flow, a good foot valve should be installed on the submerged end of the suction pipe. This ensures that water will remain in the suction line when the pipe is stopped, and will not drain back to the source of supply.

Suction conditions are one of the chief sources of trouble on a centrifugal pump; they are best taken care of by giving careful thought to the location of the pump, before it is actually installed. Total suction lift depends upon:

1. Vertical distance between the surface of the supply source and the centerline of the pump.
2. Length and diameter of the suction line.
3. Valves and fittings in the suction line.
4. Height of the pump above sea level.
5. Temperature, pressure, and viscosity of the liquid being pumped.

Operation

A detailed set of procedures for putting a centrifugal pump into service is given in Chapter 7 of *Utilities Man 3 and 2,* NavPers 10656-C. Briefly summarized, the steps are as follows:

1. Open the casing drains (inlet and exhaust).
2. Lubricate where necessary (sump tank, bearing housings).
3. Open the suction valve.
4. Open the discharge valve.
5. Prime the pump.
6. Start the prime mover.
7. Check the packing glands and seals for proper lubrication.
8. If air is entrained in the system, open the air cock long enough to release it.

Wear on the pump will be lessened if the water can be strained before it enters the suction line. Excessive wear caused by pumping sandy water can result in the impeller becoming unbalanced, and pump and engine will vibrate. Unless this unbalance is corrected, the crankshaft may break under the strain.

At times it may be absolutely necessary to pump muddy or sandy water. To prevent sediment from settling inside the pump case, and plugging the priming hole, you should drain the pump after a period of use. If you find that the priming hole is plugged, clear it by removing the drain plug at the bottom of the pump.

It occasionally happens that a centrifugal pump will stop discharging after a period of operating at full capacity. The reason may be that air is leaking into the suction line or the stuffing box. Check to see if the water seals are clogged, or if the packing does not fit properly.

In operating a pump that has a valve in the discharge line, you must be careful not to keep this valve closed for too long a period. As the water continues to circulate in the pump housing, its temperature rises. If the water gets too hot, it may damage the seal.

In extremely cold weather, never allow an idle pump to stand full of water, since freezing of the water could burst the pump. Remove the plug at the bottom of the housing, and drain the pump.

When you are ready to secure a centrifugal pump, you should first secure the driving mechanism, and then close suction valve and discharge valve, in that order.

Maintenance

Excessive vibration of a pump may be due to a poor foundation, misalignment, or unbalance of the impeller, because of partial clogging. Look to see if any of these conditions exist, before checking for possible mechanical defects.

If pump pressure is unaccountably low, make sure that you have brought the pump to its correct operating speed. Check for possible air leaks. An incorrect discharge valve open in a manifold may be allowing discharge into an open line, thus causing the pump to operate at other than the designed point.

Excessive noise during operation may mean that the clearances between impeller and casing are too great. It may also indicate too high a suction lift, or poor layout of the suction piping.

Loose main bearings should be reported immediately, since they can cause excessive wear on the impeller, and

may result in failure of the grease retainer and seal. It is advisable to take the temperatures of pump bearings at regular intervals. If oil rings are fitted, make sure that they are revolving.

The only pump part that will require lubrication is the seal. Fill the grease cup with a good grade of lime-base waterproof grease; do not use common soda soap grease, as this is soluble in water.

Packing failures are common. You should inspect packing at regular intervals, and renew it if it has become hard or charred. Use soft packing, so that the shafts will not be scored, and tighten the glands evenly. When a water seal is fitted, the gland should be adjusted so that the water trickles out from it.

Poor alignment between shaft and impeller results in vibration, and this can impair packing. Worn sleeves on the pump shaft, or worn bearings, can cause packing failure.

Any leak around the seal, between pump and engine, should be repaired as soon as it is noticed. If you continue to operate the pump with a leaky seal, water may enter the crankcase, emulsifying crankcase oil and damaging bearings. If the pump cannot be shut down immediately, so that the leak may be repaired, at least watch the cylinder oil in the engine, and frequently drain it.

If you find that the pump is overloading the driver, look to see if the speed is too high, or if foreign matter is causing rubbing in the pump. Mechanical defects that could cause overloading of the driver are: worn bearings, bent shaft, binding of the rotating element.

A pump may fail to deliver water, after it is put into operation, if it has not been brought up to the correct operating speed. Again, it may not have been sufficiently primed, or the impeller may be clogged. A less usual cause may be that rotation is in the wrong direction; this could occur after a motor overhaul.

A partly clogged impeller, or a speed less than the correct operating speed, may also result in a discharge that is only a part of the rated capacity. Short capacity may also be caused by fouled suction strainers, worn wearing rings, damaged impellers, or defective casing gaskets. Where a pump is handling hot water, suction from a source at too low a level will reduce discharge.

If a pump that has been put into operation successfully starts dropping water or losing capacity, look for leaks in the suction line. If no leaks are found, check to see if the water seal is plugged, or if the suction lift is too high.

For emergency repairs, it is wise to keep on hand an extra supply of low-priced packing. If the packing material is nonmetallic, a spare set of gland packing rings should be available. Normally, these are the only repair or spare parts that you will require. However, if a pump is so badly damaged that you must order repair parts, remember to give size, figure number, and serial number of the pump, as stamped on the nameplate.

Tests and Inspections

Once each day, all idle pumps should be turned by hand.

Once each week, all pumps should be turned by power, and the operation of the discharge check valves should be inspected.

Once each quarter, foundation bolts and dowel pins should be examined. Bearing clearances should be checked, and water-lubricated bearings and shafts should be inspected for signs of wear or scoring. The setting of overspeed trips (if fitted) should also be checked.

At least once each year, all pumps should be opened, inspected, and cleaned. Give special attention to impellers, diffusers, shafts, and shaft sleeves. Check impeller clearances, bushing clearances, and the clearances of wearing rings.

Safety Precautions

Because of its simple construction, the centrifugal pump requires practically no attention when it has once been put into operation. Similarly, there are only a few safety rules that need to be observed.

Never turn a pump over by hand with the power drive energized.

Where relief valves are fitted, make sure that they function properly.

Where speed-regulating or speed-limiting governors are fitted, see that they are set so that rate speed cannot be exceeded by more than 5 percent for any condition of loading.

ROTARY PUMPS

You will find a fairly extensive discussion of the positive displacement rotary pump in Chapter 7 of NavPers 10656-C, but we might take time here to quickly review the most important features of this class of pump.

A rotary pump is one in which a rotor actuates pistons, plungers, gears, or drums. It combines the positive displacement of the reciprocating pump with the simplicity of the centrifugal pump.

The common type is the rotary gear pump, with only two moving parts—the pumping gears, or cams, that rotate in an accurately fitted casing, with close tolerances between gears and casing, and between casing and end faces of the rotor.

The gears are mounted on parallel shafts, and mesh together moving in opposite directions. As they move, they push the liquid around the casing and through the discharge outlet, and a vacuum is created. This causes liquid to rush in on the suction side in a steady flow. Once the liquid has entered the gear chamber, it is prevented by the intermeshing gears and the close tolerances from leaking back from discharge to suction.

Figure 3-10 illustrates a rotary gear pump.

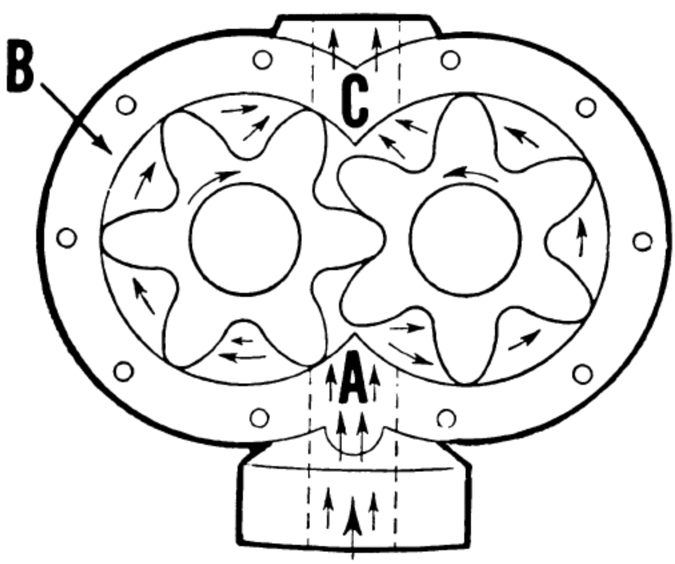


Figure 3-10.—Rotary gear pump. A, suction; B, casing; C, discharge.

In recent years, the rotary pump has largely supplanted the reciprocating pump in services where gasoline, diesel oil, and lubricating oils must be pumped. Since these pumps are essentially self-priming, and capable of producing a high suction lift, they are also used for pumping water.

Installation

This class of pump is of such simple construction that its installation presents no real problems. The pump is compact, usually without valves, except relief valves and discharge check valve. It may be belt, chain, or gear driven. It is not a high speed pump; it has a range from 100 to 1500 rpm, but increasing the speed results in noiser operation.

Most pumps that you will use will probably be set to operate between 400 and 500 rpm. Quantity of discharge depends upon the speed of the shaft rotation, as well as upon the size of the pump. Discharge occurs at a uniform rate, and the pump does not require full load to bring it up to speed.

If viscous liquids are to be pumped, you should install the pump so that it has a suction head rather than a suction lift.

Operation

Where suction is only a few feet, it will not be necessary to prime the rotary pump before starting it. An old pump, on which the clearances have worn larger, may need priming.

The clearances must be kept to a minimum in order to reduce slippage; but with such close clearance, you cannot have a reliable operation, and maintain capacity over a period of time, unless you operate at a relatively low speed. The greater the speed, the greater will be the erosive action caused by wire drawing of the liquid through the narrow spaces between gear teeth and casing.

The procedures for putting the pump into service are as follows:

1. Make sure that the discharge valve is open.

2. Fill the oil cups, and check the oil level in the sump tank or bearing housing. If the rotary pump is lubricated by a detached pump, open and adjust all oil delivery and return valves.

3. Open valves (where fitted) on pump packing gland seals.

4. Lift relief valves by hand.

5. Open the pump suction valve.

6. Start the prime mover.

7. Check the bearings for proper lubrication.

8. Adjust the shaft packing glands.

Running conditions are about the same as for a centrifugal pump. Bearing lubrication is about the only attention that is needed.

When you are ready to secure the pump, you first stop the prime mover. You then make sure that the discharge check valve is closed, and close the suction valve. Of course, if the unit is lubricated by a separate pump, you must close all supply and return valves.

Maintenance

Maintenance requirements are minimum on this class of pump, since all internal parts are lubricated by the flow of the liquid being pumped. Clearances are perhaps the most important factor; when they have worn too large, the pump itself will have to be replaced. Fortunately, this class of pump is not unduly expensive.

All clearances and tolerances should be maintained in accordance with manufacturers' instructions. On a low-pressure low-suction pump, the clearance may be between 0.005 in. and 0.010 in.

Gears must be in correct phase, so that they will mesh properly; they must be rigidly secured on the shafts, and there must be no lost motion in key ways and shafts.

Packing requirements are about the same as for other pumps. When the pump is used for oils or oily liquids, you should have a spare set of packing glands on hand.

Perhaps the two most common troubles that arise in connection with a rotary pump are: failure of the pump to build up discharge pressure, and leakage from the

discharge to the suction side. This latter is due, as mentioned before, to excessive clearances between rotating parts, or between rotating and stationary parts.

When a pump fails to build up discharge pressure, stop the unit, and check the suction valves. Air leaks or want of priming may also be the cause. If your vacuum is less than 5 in., check the packing glands on the suction side, and the pump shaft packing, for air leaks. If there is no vacuum, the pump is not primed. If the pump is primed, and a good vacuum builds up, but no pressure develops as you close the discharge valve, you had better look for an obstruction in the suction line, or for a clogged strainer.

Vapor lock in the suction line should be checked for only after other possibilities have been explored. The causes of vapor lock are usually too much length of suction line, or a rise in the temperature of the liquid being pumped.

When proper maintenance requires the dismantling of the pump, proceed as follows:

1. If the space about the pump is too limited for proper handling of the job, remove the entire unit to a more convenient location.
2. Remove the casings and the bearings. Note carefully the location of each part as you remove it; identify it, if possible, with a stencil.
3. Keep all parts together in a suitable container.
4. Clean the end plates, and give them a coat of white shellac.
5. Replace all worn parts.

In reassembling the pump, use the manufacturer's plans, if they are available; in any event, you must assemble the parts in their correct positions. All parts should run freely, except for a slight drag caused by the stuffing box. Improper reassembling will result in faulty operation.

A complete dismantling of the pump should be done at least once a year. A quarterly check should be made on the position of the pump rotors, and on clearances. With the pump full of liquid, close the suction valve, and check the amount of vacuum that the pump pulls. If the vacuum is not up to specifications, open the pump and adjust or renew the parts so as to restore the proper clearances.

All other tests and safety precautions are the same as those specifically listed in the preceding section, "Centrifugal Pumps."

HI-LIFT PUMPS

The Hi-Lift pump, used by the Army, is especially designed for the installation in 4- or 6-in. cased wells. This class of pump has three essential parts: a turbine pump, which utilizes the effect of whirling water to develop flow pressure; a plunger pump, to apply this pressure directly to the liquid being pumped; the Hi-Lift pump, in which the displacement of a piston in a cylinder results in actual flow.

Figure 3-11 illustrates the general assembly of a Hi-Lift pump, and figure 3-12 shows the detail of the pump bowl assembly.

The pumping element consists of a chrome-plated rotor revolving inside a cutless rubber stator. As the rotor rolls on the stator surface, it forces the liquid ahead of it; since the rotor speed is relatively slow (usually about 1800 rpm), there is minimum disturbance of the liquid. The rolling action is continuous, and this, with the constant-displacement cross section, ensures uniform flow.

When installing a Hi-Lift pump, you should employ column pipe of standard weight. Use 10-ft sections, except just below the pump head and just above the pumping element, as indicated in figure 3-11. The shafting, of course, must correspond to the lengths of the column pipe sections.

When the pump is in service, the pumping element and the column pipe must be full of liquid, to protect the rubber bearings. A combination strainer and foot valve attached to the stator strains out large particles of foreign matter, and prevents liquid that has already entered the pump system from draining back to the source.

If water hammer develops when the foot valve is suddenly closed, you should install a check valve in the suction line, close to the pump, and designed to close slightly in advance of the foot valve.

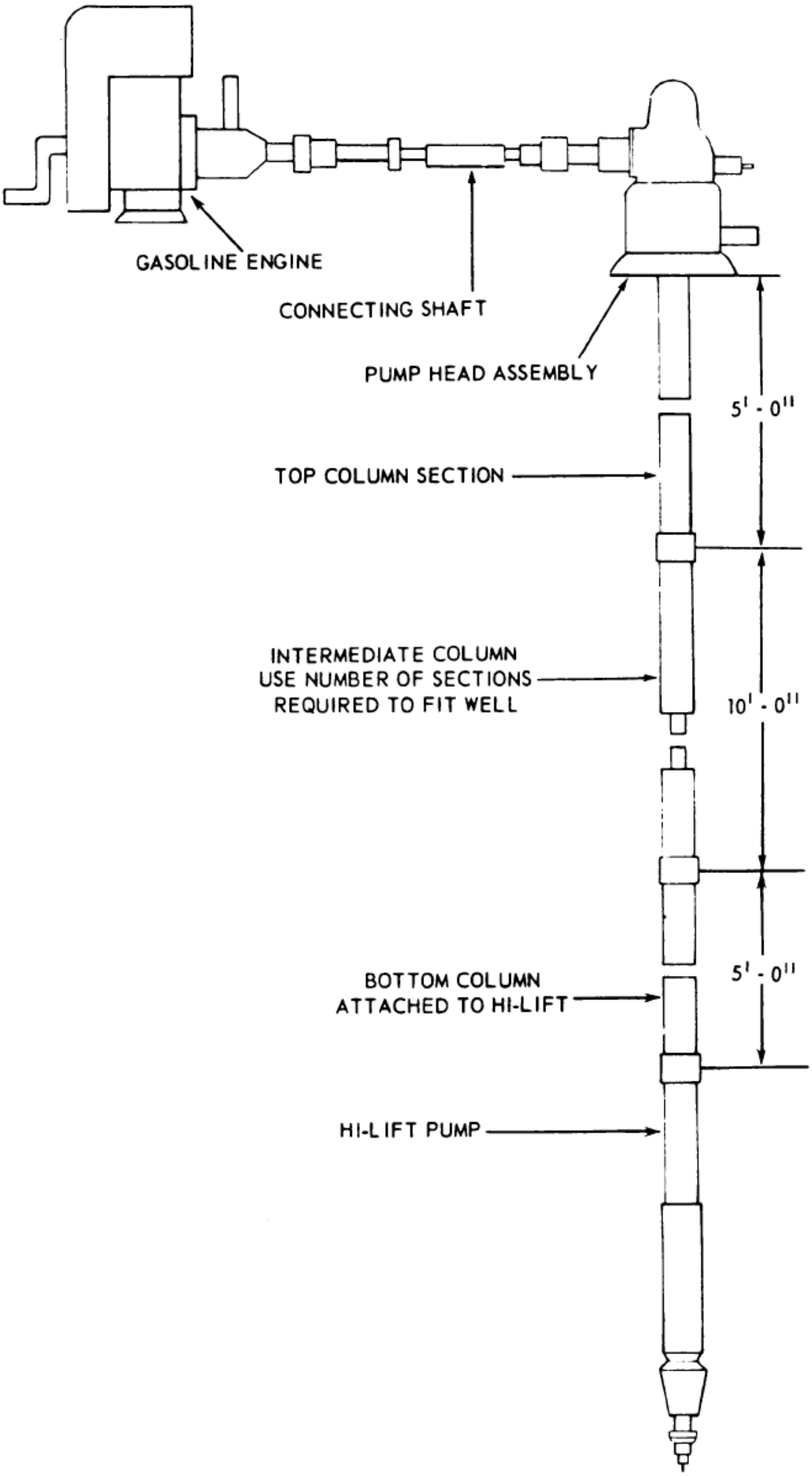


Figure 3-11.—Hi-Lift pump assembly.

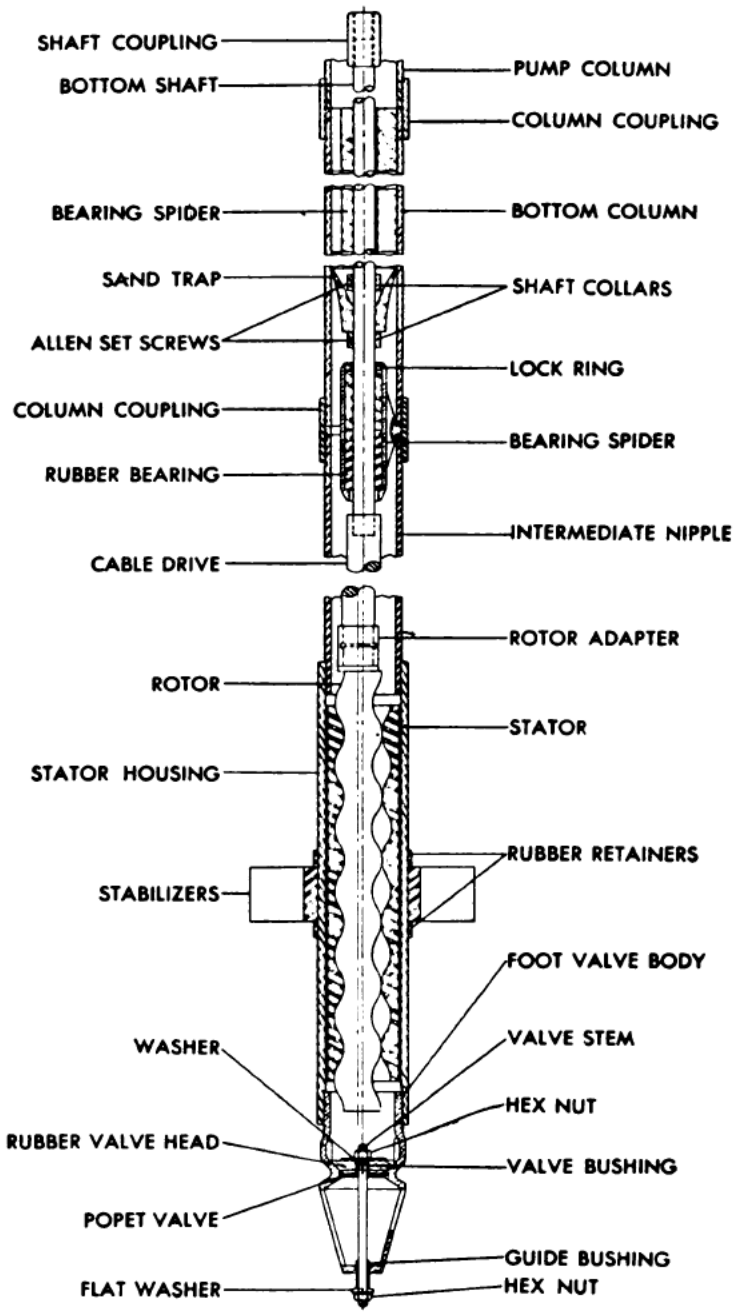


Figure 3-12.—Bowl assembly of a Hi-Lift pump.

AIR LIFT PUMPS

The principle of an air lift pump is to increase suction lift in the water pipe by introducing compressed air. The resultant mixture of air and water has a lower specific gravity than water, and will consequently rise to a much higher level in water pipe than would water alone.

Two pipes are submerged into the water supply source; one is the water pipe, and the other is the pipe for conducting the compressed air. An inlet low down in the rising main (water pipe) provides for the introduction of the stream of air. Figure 3-13 illustrates the arrangement. In Chapter 7 of *Utilities Man 3 & 2,* NavPers 10656-C, there is a diagram illustrating the principle of the air lift pump.

The compressed air is released into the water pipe through a foot piece, or diffuser. The bubbles must be small enough so that the effect is that of a lower specific gravity in the mixture, and not that of a column of water being pushed upward by a jet of air.

The component parts of an air lift pump are: air compressor, receiver for compressed air, air pipe to borehole, rising main, and receiving tank.

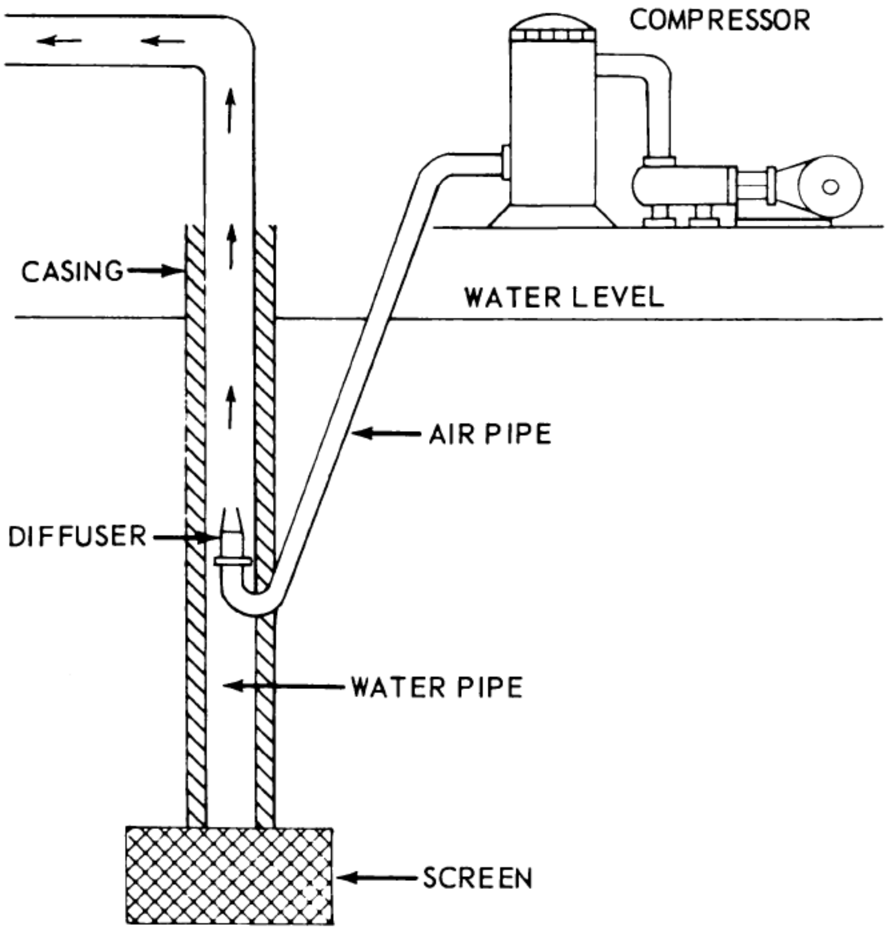


Figure 3-13.—Air lift pump.

The air compressor is single stage for pressures below 60 psi; for pressures of 60 psi and above, two stages will be required.

The air pipe leading down to the borehole at the entry to the rising main should be outside the rising main casing, if possible, to reduce friction.

Cross-section area of the rising main should be about six times that of the air pipe and submergence of the rising main should be at least one and one-half times as great as the lift.

Cross-sectional area of the air pipe depends upon the volume and the pressure of the air that is to be transmitted. A footpiece installed between air and water pipe serves to admit the compressed air into the discharge pipe; this footpiece should be capable of dividing the air into small streams.

Delivery of the correct amount of air is important. Too much air causes excessive friction; too little air causes intermittent discharge.

When the pump is put into service, the starting pressure must equal the depth of water over the submerged end of the air pipe, or over the footpiece. After the pump is operating, pressure will level off at a constant which is equal to the depth of the water that is outside the well casing and above the footpiece, plus the friction loss in the pipe.

Since there are no remote or submerged moving parts, maintenance for this type of pump is simple. However, the well must be deeper than for other types of pumps, and efficiencies are low—maximum about 50 percent, but with average efficiency much lower.

The advantages and disadvantages of the air lift system should be carefully considered before decision is made to use an air lift pump. The chief advantages are: simplicity; air pipe may be run down at an angle to the rising main; hot liquids can be handled as easily as cold liquids; and sand or other impurities in the liquid will not be detrimental to the pump. Offsetting these advantages are the facts that (1) the efficiency of this system is low, (2) discharge is feasible only in a vertical direction, and (3) oxygen in the air makes the water more corrosive.

JET PUMPS

A jet pump is a simple mechanism, consisting of a suction line to a suction chamber, a jet or nozzle, and a diffuser. These pumps are really eductors, since they have no moving parts, and the flow is maintained by the velocity of the jet (steam or water) through the nozzle. Figure 3-14 illustrates the operating principle of a steam jet pump.

Although not suitable for use in large water supply systems, jet pumps are widely used in low-capacity installations. They are available in sizes ranging from 20 gpm capacity at a 150-ft lift to 70 gpm capacity at a 30-ft lift. They are particularly serviceable for removing water from wells.

A jet pump can be employed as part of an installation for pumping well water. Install a motor-driven centrifugal pump at ground surface; this pump should have two discharge pipes, one of which leads water downward to the jet, which discharges it at high velocity. This velocity

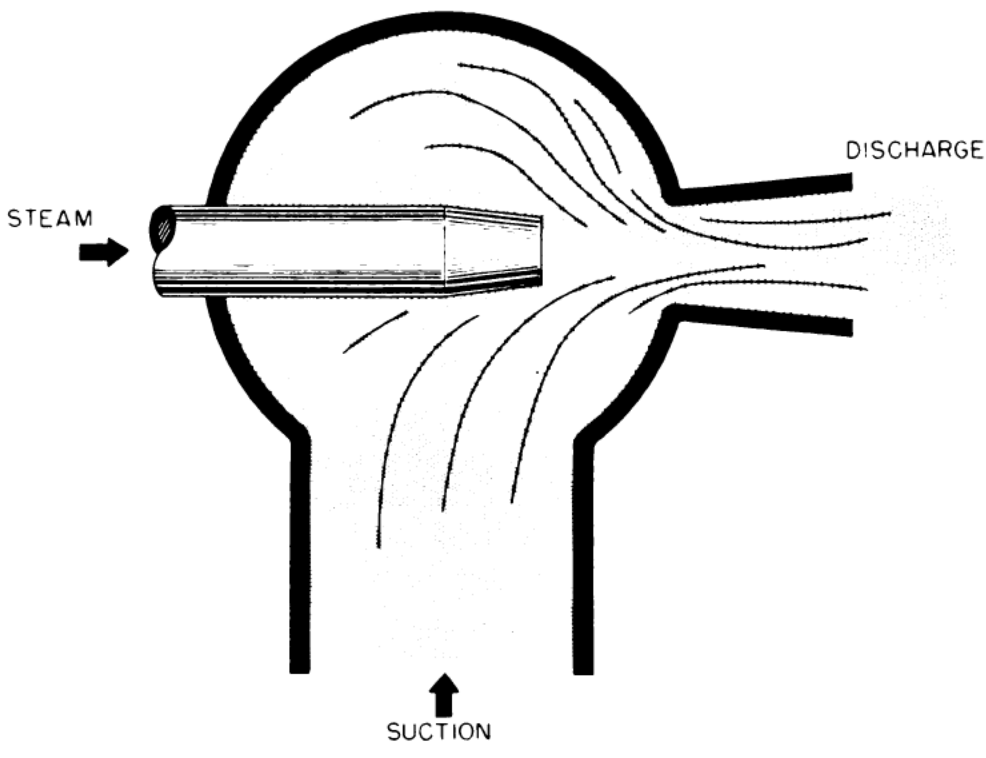


Figure 3-14.—Operating principle of a steam jet pump.

serves to lift the water into the suction of the centrifugal pump.

COMPARISON OF CLASSES OF PUMPS

The many uses to which pumps can be put render it difficult to make hard and fast rules for their selection. However, a few general comparisons can be given here, and they may prove helpful when a decision must be made as to which class to employ.

Reciprocating pumps are preferable when heavy oils must be pumped in large quantities.

Reciprocating pumps give longer service than other types of pumps when the liquid handled contains grit or other abrasive matter.

Reciprocating or rotary pumps will probably prove better than centrifugal pumps when the service calls for operating with a high suction lift.

Centrifugal pumps are suitable for operation under very high heads. They will handle liquids at temperatures up to 1000 F. Throttling the discharge will not overload the driving unit, or build up undue pressure.

Centrifugal and rotary pumps in general are more dependable then reciprocating pumps, because of the simplicity of their design.

Air lift pumps are suitable for lifting oil or water from wells, and can be used in crooked shafts, where no other type of pump would serve. Also, an air compressor in a central station can be used for a group of wells.

Jet pumps will discharge against moderate pressure, and can successfully operate when entirely submerged.

QUIZ

1. What 3 methods of classifying pumps are commonly employed?
2. When the level of a pump is below that of the fluid to be pumped, the movement of the fluid is by
    a. discharge lift
    b. suction lift
    c. gravity flow
    d. vacuum flow
3. What is meant by the term "discharge head"?

4. What 4 factors must be carefully considered when a pump is to be installed?
5. Under ideal conditions, the highest suction lift that a pump can possibly maintain is
   a. 14 feet
   b. 34 feet
   c. 64 feet
   d. 84 feet
6. Should you check the alignment of the coupling halves of a pump with the halves separated or with them connected?
7. Total dynamic head of a pump is usually computed by measuring the distance from the
   a. source level to the intake level of the pump
   b. inlet level of the pump to the level in the delivery tank
   c. inlet level of the pump to the highest point in the delivery pipe
   d. source level to the highest point in the delivery pipe
8. To determine pressure in lb for a vertical pipeline, multiply the height of the pipeline in feet by
   a. 0.434
   b. 0.7854
   c. 2.3
   d. 3.1416
9. Why is it that greater friction loss occurs at bends and fittings than in an equivalent distance of straight piping?
10. Is frictional loss in a piping system greater for a 6-in. diameter pipe than for the same length of 3-in. pipe?
11. In a reciprocating pump, how is the rotary motion of the crankshaft converted to the straight-line motion of the piston?
12. A double-acting reciprocating pump is one that is equipped with
    a. two strokes, suction and discharge
    b. two crank pins, set 90 degrees apart
    c. two pistons, one at either end of the cylinder
    d. two cylinders, one at either end of the plunger
13. What is the purpose of staggering the joints of piston rings on a steam-driven reciprocating pump?
14. The formation of shoulders in the cylinder of a reciprocating pump is caused by
    a. breaking of rings and followers
    b. too short a stroke
    c. incomplete cushioning
    d. packing gland too tight in stuffing box

15. If the steam piston of a reciprocating pump that has been idle for some time, freezes when the pump has been put into service, what check should you make on the main steam valve?
16. When you are securing a reciprocating pump, you should position the steam cylinder drains so that
    a. both the top and bottom drains are closed
    b. both the top and bottom drains are open
    c. the bottom drain is closed, the top drain open
    d. the bottom drain is open, the top drain closed
17. If a properly packed gland continues to leak after it has been given a few turns on the nut, what is the probable cause?
18. When a reciprocating pump is working so poorly that you know it must be in need of repair, what part should you check first?
19. If the piston rings in the steam cylinder have worn to excessive clearance, the best remedy is to
    a. replace the packing gland
    b. replace the liner
    c. replace the rings
    d. none of the above
20. What operating precaution must be taken before a centrifugal pump is started, after being lined up for use?
21. Which type of centrifugal pump is better for use where the liquid contains grit and suspended matter?
22. Which type of centrifugal pump is better for use where the volume of liquid pumped is small in relation to the head?
23. When flow is reduced or stopped in a centrifugal pump, to what extent does pressure build up?
24. In the choice of a site for a centrifugal pump, why is suitability for the driving mechanism the first consideration?
25. A centrifugal pump can be provided with flooded suction, to eliminate the need of priming, by
    a. setting the pump at a level lower than the water supply
    b. using a steam jet to ensure suction lift
    c. using compressed air to ensure suction lift
    d. setting a small vacuum pump to create a vacuum in the suction line
26. Why is it advisable to strain the water before it enters the suction line of a centrifugal pump?
27. In operating a centrifugal pump, why is it poor practice to close the discharge line valve for an extended period while the pump remains in operation?

28. What will happen if you continue to operate a centrifugal pump where the seal between pump and engine is leaky?
29. If a centrifugal pump fails to deliver water after it is put into operation, what 4 factors should you check for?
30. If a centrifugal pump begins losing capacity after it has been successfully put into operation, what 3 factors should you check for?
31. In a rotary gear pump, what are the moving parts?
32. How is the liquid passing through a rotary gear pump prevented from leaking back to suction?
33. Quantity of discharge in any specific rotary pump depends upon the
    a. provision of a suction head rather than a suction lift
    b. provision of a suction lift rather than a suction head
    c. speed of shaft rotation
    d. pump operating at full load
34. In a rotary pump, what is the relation between clearances and speed?
35. What is the method of lubrication for internal parts of a rotary pump?
36. When a rotary pump fails to build up discharge pressure, what 3 factors should you check?
37. What are the 3 essential parts of a Hi-Lift pump?
38. What are the 5 component parts of an air lift pump?
39. When an air lift pump is put into service, what starting pressure in needed?
40. How is flow of liquid through a jet pump maintained?

CHAPTER 4

REFRIGERATION

Refrigeration is the process of removing heat from matter by the use of a colder medium, the refrigerant. Proper control of temperatures and pressures to which a refrigerant is subjected makes it possible for the fluid to take up heat from surrounding matter. This absorbed heat is then released to water, to the atmosphere, or (as in shipboard refrigerating systems) to the sea.

As a Chief Utilities Man, or a First Class, you must have a clear understanding of the basic principles of refrigerating plants. You must have a knowledge of the kinds of heat, how it is measured, and the ways in which it is transmitted. You must know how a refrigerant can change from one form of matter to another (solid, liquid, and vapor) in response to variations in temperature or pressure.

A brief discussion of basic principles and theory is given in Chapter 6, Basic Refrigeration, of *Utilities Man 3 and 2,* NavPers 10656-C. A much more detailed explanation is necessary before you can understand refrigeration well enough to install, operate, and maintain a system, and to instruct lower-rated men in its operation and repair.

The opening pages of this chapter repeat some of the subject matter that you learned as a striker or third class. This repetition seems advisable, in order to unify what you have already learned with what you are about to study. It will also serve to bring what might otherwise be isolated facts into proper relation with each other.

HEAT THEORY

Heat is a form of energy. It is invisible, but it is known by the effects which it has on the surrounding air, the human body, and on other matter. As energy, however, it can be considered in terms of input and output, and devices are available for measuring its intensity and quantity.

Kinds of Heat

When the application of heat to a body or substance raises the temperature of that body, but does not bring about a change of state (that is, a conversion from solid to liquid form, or from liquid to vapor), the heat is known as SENSIBLE HEAT.

When the application of heat brings about a change of state in a body or substance, the heat is known as LATENT HEAT. The use of the word latent means that the heat is "hidden"; that is, it does not bring about an increase or decrease in the temperature of the substance affected, but shows its presence (or loss) by causing a change of state.

This change of state may be the conversion of a solid to a liquid, or of a liquid to a vapor. It may also be the reverse process of condensing a vapor to a liquid, or a liquid to a solid. The accomplishment of the first process (fusion or vaporization) requires the application of latent heat. The second process (condensation) releases latent heat.

The amount of latent heat released when a given volume of liquid is changed to a solid, or when a given volume of gas (vapor) is changed to a liquid, is exactly equal to the amount of latent heat that was required to bring about the change of that same volume of the substance from solid to liquid, or from liquid to vapor.

SUPERHEAT is the amount of heat present in a substance above the temperature required to raise that substance to its boiling point. In the preceding chapter, Boilers and Boiler Controls, this need for maintaining a temperature of more than 212 F was discussed. In refrigeration, superheating assures that all liquid refrigerant will be completely vaporized before it enters the compressor.

SPECIFIC HEAT is the amount of heat required to raise a unit weight—usually 1 lb—of a substance 1 F in temperature. (Amount of heat is explained in the following section, Units of Heat.) Specific heat differs for various substances, and it is the custom to express specific heat in decimals, with the specific heat of water set at unity. Thus, cast iron has a specific heat of 0.119; ice, 0.504; and alcohol, 0.70.

TOTAL HEAT is a term that may have more than one meaning, according to the context in which it is used. When used in connection with refrigeration, total heat refers to the sum total of sensible heat and latent heat.

Units of Heat

In measuring heat, there must be a distinction made between intensity and quantity. The amount of heat in a pail full of warm water, for example, may be greater than the amount in a small quantity of boiling water; but the intensity of heat in the boiling water will be much greater than that in the warm water.

INTENSITY of heat is so high in some types of work involving the use of furnaces that special temperature-measuring devices are necessary. Such devices are usually electric resistance thermometers, thermocouples (where the temperature is measured in terms of the production of a thermoelectric current), and optical pyrometers (where temperature is measured in terms of the intensity of heat or light radiated).

However, the usual method of measuring heat is by the use of the common thermometer. Here the intensity of heat is measured by a gradation based upon the distance between freezing point and boiling point, although the scale actually extends below and above these respective points.

The thermometer with which we are all familiar is the one using the Fahrenheit scale, which sets 32 degrees as the point at which water solidifies, and 212 degrees as the point at which water at atmospheric pressure converts to steam. Other thermometers, each with its own scale, are used in various types of work or research. The centigrade scale thermometer, which shows freezing point at zero, and boiling point at 100, is employed in practically all scientific work.

Both Fahrenheit and centigrade are usually mercury thermometers. Since mercury freezes at minus 39 C, and boils at 357 C, even the centigrade thermometer will not prove universally adequate for laboratory work in relation to various thermal phenomena. The Kelvin (or absolute) scale thermometer must sometimes be employed; its freezing point is 273, and its boiling point is 373 degrees.

QUANTITY of heat possessed by any substance is measured in terms of Btu's. This unit (British thermal unit) is the quantity of heat that would be required to raise 1 lb of pure water, at some temperature between 32 F and 212 F, one degree higher.

In the preceding section, it was mentioned that the specific heats of various subjects are expressed as decimals, with the specific heat of water as a standard. A Btu is therefore defined in terms of heat required to raise the temperature of 1 lb of water 1 F; but the number of Btu's needed to raise 1 lb of various substances 1 F will naturally differ. In place of "the amount of heat" in the definition given earlier for specific heat you can read "the number of Btu's."

Temperature-Pressure Relationships

The boiling point of a liquid is understood to mean boiling point at atmospheric (sea level) pressure. Variations in altitude, with consequent lowering of barometric pressure, result in some slight lowering of the boiling point. For example, at 1,000 ft above sea level, water will boil at 210 F.

This reference to the variation of pressure and temperature at different altitudes is used only as an indication of the importance of pressure in changing a substance from liquid to vapor, or from vapor to liquid. The real importance of this phenomenon lies in the fact that pressure adjustments obtained by mechanical means can be utilized in place of temperature changes to vaporize a fluid, or to liquefy it. The mechanical means employed may be a device such as a piston operating in a closed cylinder, or a valve.

The pressure-temperature relationship for change of state varies, as does the freezing point and the boiling

point, for different substances, but it always follows an exact law. Thus, if the volume of a gas is held constant, but temperature is varied, there will be a corresponding change in pressure. This physical law is an important factor in refrigeration.

Figure 4-1 illustrates the pressure-temperature relation of three commonly used refrigerants: Freon 12, Freon 22, and methyl chloride.

Pressure-temperature relation
(Gage pressure in psi)

Temperature (degrees F)	Freon 12	Freon 22	Methyl Chloride
-50	*15.4	*6.0	*19.4
-45	*13.3	0.1	*17.6
-40	*11.0	0.6	*15.9
-38	*9.9	1.4	*15.1
-36	*8.9	2.3	*14.3
-34	*7.8	3.1	*13.4
-32	*6.7	4.1	*12.5
-30	*5.5	5.0	*11.5
-28	*4.2	6.0	*10.5
-26	*2.9	7.0	*9.5
-24	*1.6	8.1	*8.4
-22	*0.2	9.2	*7.3
-20	0.6	10.3	*6.1
-18	1.3	11.5	*4.9
-16	2.1	12.7	*3.6
-14	2.9	13.9	*2.3
-12	3.7	15.2	*0.9
-10	4.5	16.6	0.3
-8	5.4	18.0	1.0
-6	6.3	19.4	1.8
-4	7.2	20.9	2.6
-2	8.2	22.5	3.4
0	9.2	24.1	4.2
2	10.2	25.7	5.1
4	11.3	27.4	6.0
5	11.8	28.3	6.5
6	12.3	29.2	6.9
8	13.5	31.0	7.9

*Indicates vacuum.

Figure 4-1.—Pressure-temperature relation of refrigerants.

Temperature (degrees F)	Freon 12	Freon 22	Methyl Chloride
10	14.6	32.9	8.9
12	15.9	34.9	9.9
14	17.1	36.9	11.0
16	18.4	39.0	12.1
18	19.7	41.1	13.3
20	21.1	43.3	14.5
22	22.4	45.5	15.7
24	23.9	47.8	16.9
26	25.4	50.2	18.2
28	26.9	52.7	19.6
30	28.5	55.2	21.0
32	30.1	57.8	22.4
34	31.7	60.5	23.9
36	33.4	63.3	25.4
38	35.2	66.1	26.9
40	37.0	69.0	28.6
42	38.8	72.0	30.2
44	40.7	75.0	31.9
46	42.6	78.2	33.7
48	44.6	81.4	35.4
50	46.7	84.7	37.3
52	48.8	88.1	39.2
54	50.9	91.5	41.1
56	53.1	95.1	43.1
58	55.4	98.8	45.2
60	57.7	102.5	47.3
62	60.1	106.3	49.5
64	62.5	110.2	51.7
66	65.0	114.2	54.0
68	67.5	118.3	56.3
70	70.1	122.5	58.7
72	72.8	126.8	61.2
74	75.5	131.2	63.7
76	78.3	135.7	66.2
78	81.2	140.3	68.9
80	84.1	145.0	71.6
82	87.0	149.8	74.3
84	90.1	154.7	77.1
86	93.2	159.8	80.0
88	96.4	164.9	82.9
90	99.6	170.1	85.9
92	103.0	175.4	89.0
94	106.3	180.9	92.2

Figure 4-1.—Pressure-temperature relation of refrigerants.—Continued.

Temperature (degrees F)	Freon 12	Freon 22	Methyl Chloride
96	109.8	186.5	95.4
98	113.3	192.1	98.6
100	116.9	197.4	102.0
102	120.6	203.8	105.4
104	124.3	209.9	108.9
106	128.1	216.0	112.5
108	132.1	222.3	116.1
110	136.0	228.7	119.8
112	140.1	239.2	123.6
114	144.2	241.9	127.5
116	148.4	248.7	131.4
118	152.7	255.6	135.4
120	157.1	262.6	139.5
122	161.5	269.7	143.7
124	166.1	276.9	147.9
126	170.7	284.1	152.3
128	175.4	291.4	156.7
130	180.2	298.8	161.1
132	185.1	306.3	165.7
134	190.1	314.0	170.4
136	195.2	321.9	175.1
138	200.3	329.9	180.0
140	205.5	338.0	184.9
142	210.2	346.3	194.1
144	216.0	355.0	198.4
146	221.2	364.3	202.7
148	226.8	374.1	206.8
150	232.3	384.3	210.7
152	239.3	392.3	215.0
154	245.5	401.3	220.0
156	252.0	411.3	225.8

Figure 4-1.—Pressure-temperature relation of refrigerants.—Continued.

Heat Transfer

The general law of heat transfer is that heat flows from a body at a higher temperature to a body with a lower temperature. You can see that a difference of temperature is essential to heat flow; the greater this difference, the faster the rate of heat transfer. The processes by which heat is transferred are radiation, conduction, and convection. These processes may take place singly or in combination.

RADIATION is the method by which heat energy is transferred through space. Heat is radiated not only from the sun, but to some extent it is radiated also from stoves, electric appliances, machines, buildings, the earth itself.

CONDUCTION is a form of heat transfer that takes place only when the respective substances are in contact with each other. Some substances conduct heat much more readily than others; for example, copper has a much higher degree of heat conductivity than iron. In refrigeration, substances that have the characteristics of low heat conductivity are of great practical value, since they tend to reduce the flow of heat.

CONVECTION is the process of heat transfer that takes place through the medium of air, water, steam, gas, or some other fluid. The heat is transmitted by the movement of heat-containing particles through this fluid medium.

INSULATION

It is comparatively easy to heat or cool articles or enclosed air spaces. However, because of the principle of heat transfer, it is not so easy to maintain them at the desired temperature. To prevent heat flow, or transfer, from one body to another body with a lower temperature, use can be made of those substances which have a low heat conductivity.

In general, metals are good conductors, although the degree of thermal conductivity will vary from metal to metal. Natural liquids are poor conductors. Gases are very poor conductors.

Nonmetallic solids that are poor conductors are usually porous in nature, and it is the presence of these air pores or cells, very small in size, that retards the passage of heat. Air spaces of greater size, however, would make the substance a better conductor, since they would permit transfer of heat by radiation and by convection.

The nonmetallic substances such as wood, cork, paper, sawdust, glass, rubber, asbestos, plastics, water, and dead air spaces are such poor conductors that they are used as heat insulators.

Suggested materials to use for retarding or throttling the flow of heat are:

Material	Density (lb/cu ft)	"K" Factor (conductivity)*
Cork, granulated, no binder	10.60	0.30
Balsa	7.05	0.32
Glass wool (curled pyrex)	4.00	0.29
Mineral wool, loose packed (slag)	12.00	0.26
Rock wool (fibrous rock, also felted)	6.00	0.26
Sawdust, pine	1.56	0.57
Straw fibres, pressed	8.67	0.32
Wood fibres (kingia australis)	8.40	0.33
Wool, pure	4.99	0.26

*"K" equals Btu per sq ft per hr per degree for 1 in. of thickness.

While any of the materials listed here will serve as insulation, the best choice is a material that is lightweight, and has a low heat conductivity factor. For example, sawdust is the lightest in weight of these materials (density of only 1.56 lb per cubic foot), but it has a relatively high conductivity factor. Mineral wool (slag) has a low K factor, but its weight per cubic foot of material is fairly high.

Insulation already in place may deteriorate if any leakage of milk, juices, or other liquids seeps into it. Seepage of this sort is most likely to occur at the bottom of the small, reach-in units, or in freezer units. Occasionally inspect the plastic or phenolic strips that are applied around the door opening, to act as a thermal barrier between the inner and the outer shell of the unit.

If the screws in this strip are loose or missing, remove the strip and inspect the insulation for signs of deterioration or of moisture penetration. If there is no damage to the insulation, replace the breaker strips, and tighten the screws.

Insulation that has become water-soaked or contaminated must be replaced. It will be necessary to remove some girder ribs in order to accomplish this, but keep

the number of ribs to a minimum, and never cut or remove girder ribs adjacent to hinges or latches. When the contaminated insulation has been removed, and new insulation substituted, seal along the liner and the outer casing with an odorless, nontoxic, mastic sealing compound. Since a mastic sealing compound requires no drying or setting time, you can immediately replace the breaker strips.

MECHANICAL REFRIGERATION

Simple ice refrigeration depends upon natural or forced circulation of air around ice stored in an enclosed space. The air is cooled by losing heat to the ice; the ice melts, and the water is drained away, carrying the heat with it. If the water could be systematically refrozen to replace the ice, the process could be made continuous. To some extent, this continuous process has been accomplished in the steam jet vacuum plants used aboard some ships, for air conditioning.

Most refrigeration systems, however, employ some type of volatile liquid as a refrigerant, to simplify the problem of continuous renewal. Freon 12 is customarily used as a primary refrigerant, although you may be called upon to operate systems that employ other fluids. This matter of refrigerants is discussed at greater length in a subsequent section of this chapter.

The term primary refrigerant is used to denote the volatile fluids, because in some systems there will be a secondary refrigerant, usually either water or brine. The function of the secondary refrigerant is to carry heat from the refrigerated areas and deliver it to the primary refrigerant.

Figure 4-2 illustrates in a very simple form a circuit for a refrigeration system. The compressor acts as a pump, drawing the refrigerant from the suction line and putting it under increased pressure in the compressor itself, before releasing it to the condenser. An expansion valve located in the line ahead of the cooling coils permits only that amount of liquid required for operation to pass into the coils. The effect of this valve is not only to meter the required amount, but also to maintain pressure

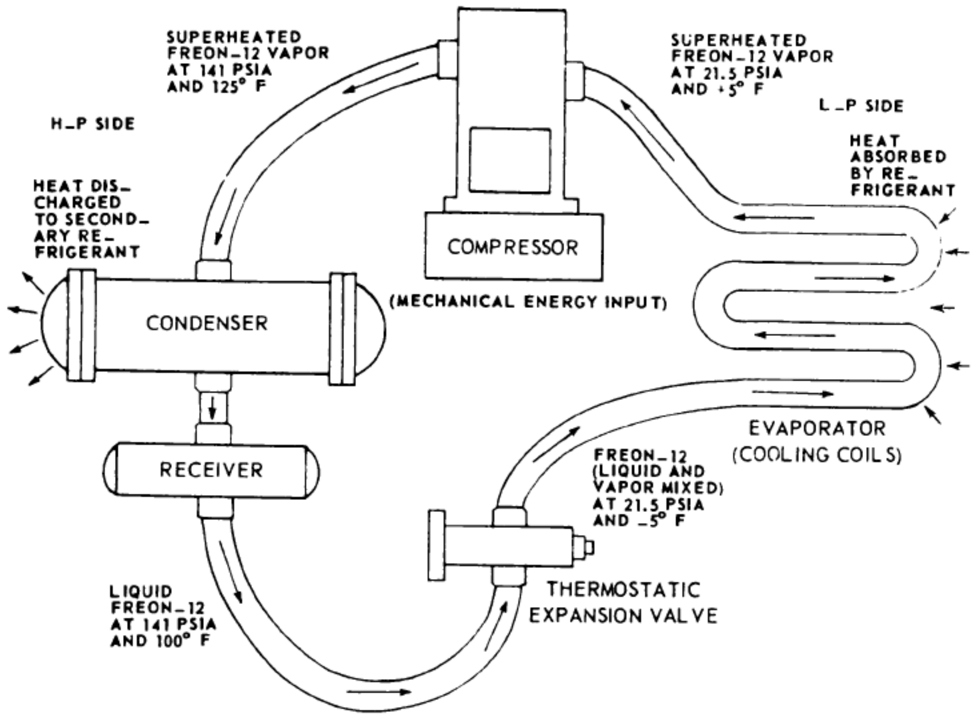


Figure 4-2.—Mechanical refrigeration cycle.

in the condensing chamber. The higher the pressure exerted on the vapor, the higher the temperature at which it will condense.

There are two types of refrigeration systems, the absorption system and the mechanical system. Absorption systems employ heat energy to bring about the changes that comprise the refrigeration cycle. Instead of a compressor, a heater or generator is installed. The compression (mechanical) system utilizes a closed circuit through which the refrigerant passes, absorbing heat in one part of the system and releasing it in another part.

REFRIGERATION CYCLE

In the vapor compression systems, the refrigeration cycle comprises four processes: compression, condensation (or cooling), expansion, and heat absorption (evaporation). The principle units of this circuit are the compressor, the condenser, the receiver, the expansion valve, and the evaporator. These compression systems

are sealed in airtight, leakproof mechanisms, and the vaporizing and condensing processes are continuously repeated. Figure 4-3 illustrates the circuit through which the compression cycle moves, and shows the relative location of the various units, including valves and pressure- and temperature-measuring devices.

The cycle consists primarily of a high pressure side and a low pressure side. The low pressure side is that part of the system from the expansion valve forward to the low pressure side of the compressor. The high pressure side is that part of the system from the high pressure side of the compressor forward to the expansion valve. These two sides provide the temperature difference that is necessary for the transfer of heat. The refrigerant, when subjected to the reduced pressure on the low pressure side, is able to vaporize (or boil) at a lower temperature. As it evaporates, it absorbs heat from the product and space inside of the refrigerator.

In the compressor, the refrigerant vapor is subjected to a building up of pressure, and it enters the condenser as a high pressure-high temperature gas. The cooling medium which surrounds the condenser coils absorbs the sensible and latent heat, and consequently causes the high pressure-high temperature vapor to condense, and change to a high pressure-high temperature liquid.

On the low pressure side, therefore, the refrigerant is made to evaporate by lowering the pressure; on the high pressure (or discharge) side, the refrigerant is made to condense by losing heat to the cooler surroundings. As the refrigerant flows from the condenser to the receiver to the expansion valve, it is under the same pressure as that at which it left the compressor. After passing through the expansion valve, the refrigerant is subjected to a lower pressure, and the cycle is repeated.

Pressure and temperature measurements are recorded on both the low pressure and high pressure sides of the compressor. Temperature of the refrigerant is recorded again as it leaves the receiver. The expansion valve, by its operating principle, maintains the required balance between temperature and pressure. This will be more evident after you have studied the section on Expansion Valves, later in this chapter.

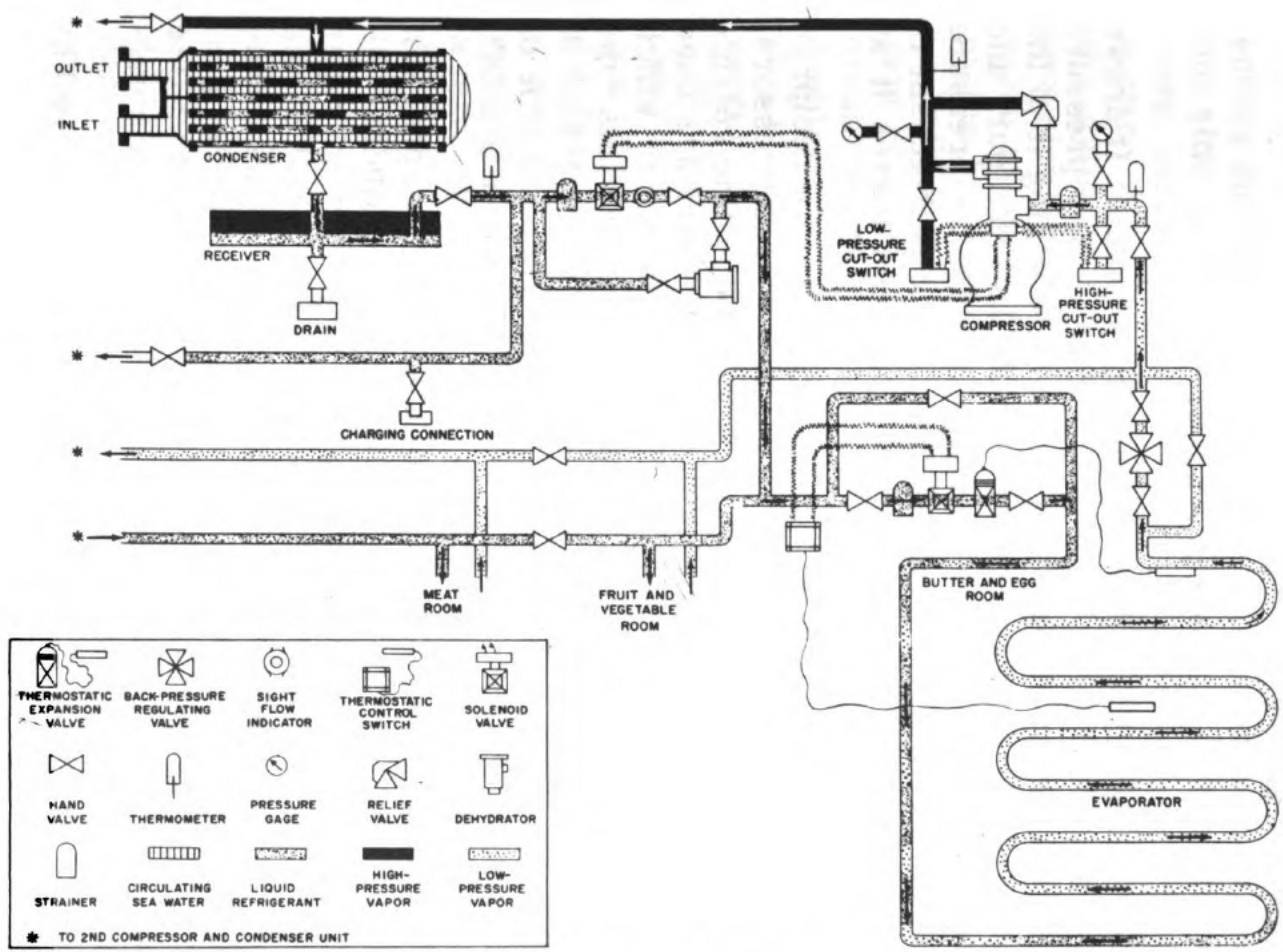


Figure 4-3.—Compression refrigeration system.

Inasmuch as a vapor compression system permits the continuous repetition of the four processes of the cycle, we may start at any point in the system to describe the units through which the refrigerant is conducted. Suppose we start with the compressor unit, shown at the upper center of figure 4-3.

Compressor

The COMPRESSOR is essentially a pump. It draws the refrigerant from the suction line, or low pressure side, and raises its pressure before releasing it to the condenser. Pressure gages on both the low pressure and the high pressure sides of this unit indicate the pressure rise. In figure 4-2, you will see that the refrigerant is drawn into the compressor at 21.5 psi, and leaves it at 125 psi.

TYPES of compressors in common use are reciprocating, rotary, and centrifugal. Rotary compressors, however, are practically limited to small home refrigerators and freezers. Centrifugal compressors are used chiefly on the large air-conditioning systems in which large volumes of refrigerant must be handled; this type is relatively inefficient, but does have the advantage of being very easily maintained. The reciprocating type of compressor, therefore, will be the one that a Utilities Man is most likely to encounter.

The RECIPROCATING COMPRESSOR is composed of a piston that moves up and down within a cylinder. As the piston descends, it draws in refrigerant in vapor form, from the evaporator via the suction line. By the time that the piston has reached the bottom of its downstroke, the cylinder has a full load of the refrigerant gas. Vapor is prevented from flowing back to the suction line by a flapper valve which is located in the top of the cylinder, and which acts as a check valve.

On the upstroke, the piston pushes the vapor ahead of it, building up pressure. When enough pressure has been built up, the check valve allows some of the vapor to escape; this usually happens when the piston has completed three-quarters of the upstroke. At the end of the upstroke, the piston reverses, drawing in additional vapor as it makes the downstroke.

The simplest type of piston is a round, cast iron plug, equipped with a number of compression rings and an oil ring. The suction valves are below the valve plate, and the discharge valves above the plate.

In some reciprocating compressors, however, the suction valve is located on top of the piston. The vapor enters the cylinder through a suction port located low on the side of the cylinder. As the piston makes its downward stroke, the increasing pressure forces open the suction valve on top of the piston, and admits vapor to the cylinder chamber above the piston. On the compression (upward) stroke, the pressure causes the suction valve to close, but opens the discharge valve when the piston has traveled three-quarters of its upward stroke.

Both these types of piston action make the compression stroke only in the upward direction, and the compressors are known as SINGLE-ACTING. The so-called double-acting compressor, which produces a compression stroke when the piston moves in either direction, is essentially a combination of two single-acting cylinders.

Where an unusually large pressure differential between the low pressure side and the high pressure side is required, a series of cylinders are needed. The compressed gas from the first cylinder in the series is exhausted into a smaller cylinder, where it can be compressed to an even greater degree. This process can be repeated with a third, or with several, successive cylinders. Each new cylinder is called a stage. Cooling the vapor between each stage increases the efficiency of this system.

The ROTARY COMPRESSORS used in domestic refrigerators and freezers have three moving parts: a steel ring, a cam, and a sliding barrier. The ring and cam are housed in a steel cylinder only slightly larger in diameter than the ring. Since the ring is positioned slightly off-center, there will always be a small, crescent-shaped space at one point between the ring and the cylinder wall.

The operation of the three moving parts provides the necessary conditions for suction, compression, and discharge. As the cam spins, it carries the ring with it; as the ring moves, the crescent-shaped gap between ring and cylinder wall uncovers an inlet port from the low pressure side, and the refrigerant enters the gap. When

the ring has revolved a sufficient distance to again cover the inlet port, the vapor which entered is trapped until the gap has moved far enough to uncover the exit port leading to the condenser.

At one point, both inlet port and exit port will be within the limits of the crescent-shaped gap; that is, they will both momentarily be uncovered. This is the point at which the sliding barrier functions. Held firmly against the ring by springs, it prevents any of the vapor from passing backward to the inlet port, and ensures that it will all pass onward to the condenser. As the ring rolls around the cylinder, this process of vapor entry, compression, and expulsion is rapidly repeated.

Rotary vane compressors operate on a similar principle. A solid cylinder is set within a hollow cylinder which is of slightly larger diameter, and which has an inlet and an outlet port. The solid cylinder, like the ring in the rotary compressor, is positioned a bit off-center, so that there is always one point on its surface that is almost in contact with the enclosing cylinder. As the solid cylinder rotates, the vanes which are set in it make contact with the inner wall of the hollow cylinder. The vapor entrapped between the vanes is compressed by this rotary motion until it is released through the discharge port.

In large refrigeration plants, a relief valve may be installed across the compressor. This valve functions to protect the compressor from damage by relieving high pressure gas into the low pressure side, in the event of accidental closing of a discharge valve, or any other type of stoppage in the discharge line.

Condenser

The condenser is usually a copper or steel coil, although aluminum tubing is sometimes used. For small units, the condenser is sometimes formed of two plates with refrigerant passages stamped into them. The unit is shrouded, and is cooled by the natural convection of air passing over it. Older type condensers may be water cooled, as indicated in figure 4-4.

Larger units require some type of forced convection—for example, a fan and a fan motor, or finned tubing. The

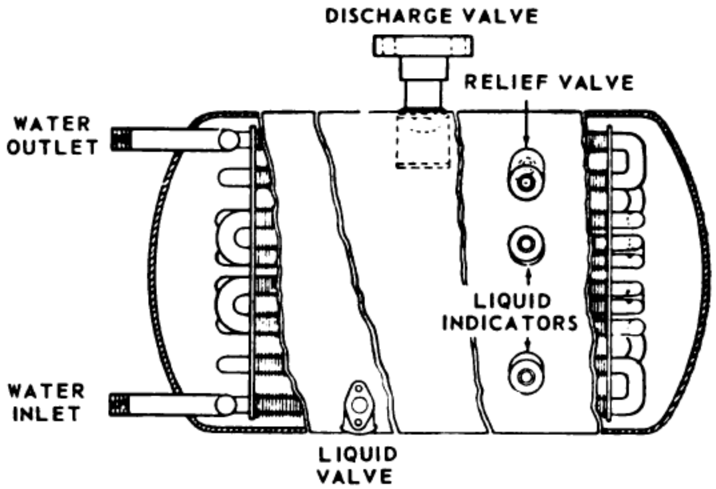


Figure 4-4.—Horizontal shell and coil, water-cooled condenser.

advantage of using fins is that they increase the surface area of the tubing, and thus promote cooling.

As vapor enters the condenser, and comes into contact with the relatively cool tubes, its temperature drops accordingly. As the vapor gives up sensible and latent heat, it converts to the liquid state, and then flows by gravity into the receiver.

Receiver

The purpose of the receiver is to serve as a storage tank for the liquid refrigerant. These receivers are part of all systems that use expansion valves (dry system) or float controls (flooded system). They are not used, however, in capillary tube systems.

As the liquid flows from the receiver, it must be at the proper temperature, as mentioned before; it should also be free from excessive water vapor. Many systems are equipped with a dehydrator, to which the refrigerant can be directed if it contains moisture. Sight flow indicators, or windows through which the operators may observe the condition of the liquid refrigerant, are a part of nearly all refrigeration systems. A solenoid valve installed ahead of the sight flow indicator serves to shut off refrigerant flow when the compressor shuts down under its safety controls.

Fine copper mesh screens at the outlets of receivers prevent foreign matter from clogging the control valves. A strainer in the liquid line just ahead of the expansion valve removes any foreign matter that might block the small orifice in the expansion valve.

Expansion Valve

The refrigerant enters the expansion valve at the same pressure at which it left the discharge side of the compressor. In the valve itself, the refrigerant undergoes a throttling process; this has the effect of lowering pressure to a point at which some of the refrigerant vaporizes. A certain amount of heat must be removed from the refrigerant as it passes through the expansion valve, going from the high pressure side of the system to the low pressure side. This must be done in order to reduce its temperature to the boiling point at the pressure in the evaporator. As part of the refrigerant boils and vaporizes, due to the reduced pressure, the remaining refrigerant is cooled to its boiling point. The cool liquid can absorb heat in the evaporator.

An electrically controlled solenoid valve, which controls the flow of liquid refrigerant to separate evaporators, is located between the strainer and expansion valve. The control is an electrically actuated thermostat switch, which indirectly maintains the desired refrigerator temperature.

The expansion valve next in the line meters the amount of refrigerant which enters the evaporator. The hand expansion valve assembly provides a means of bypassing the automatic controls in case of emergency, and also when it is necessary to accomplish cleaning or repair.

Expansion valves may vary greatly in design and construction, but the type of valve shown in figure 4-5 illustrates the basic principles common to all types. A control bulb charged with refrigerant is clamped to the suction line near the outlet to the evaporator. Temperature changes in the suction line bring about corresponding pressure changes within the bulb. These changes in pressure are transmitted through the control tubing to the diaphragm of the valve, which in turn transmits motion to the valve stem and needle.

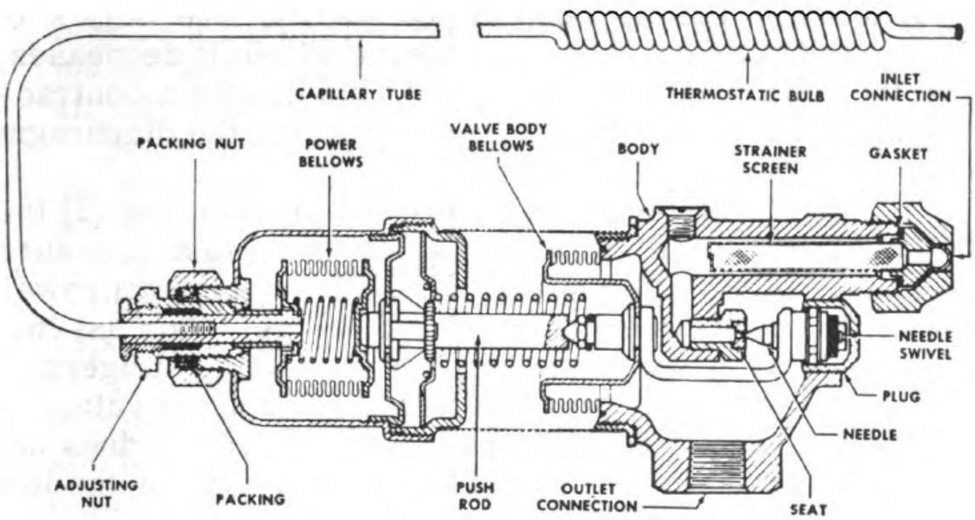


Figure 4-5.—Cross section of bellows type thermostatic expansion valve.

A description of the two most common types of expansion valve should provide you with the necessary understanding of this particular unit in any system that you may be required to operate. A further source of very helpful information is *BuShips Manual,* Chapter 59: Refrigerating Plants.

An AUTOMATIC EXPANSION VALVE is one of the division points between the low pressure and the high pressure sides of a system, and controls the passage of the refrigerant from the liquid line to the evaporator. As pressure decreases on the low side, the valve opens to allow more refrigerant to escape into the evaporating coils. As the refrigerant evaporates on the low pressure side, it absorbs the heat required to bring about this change of state. The function of this type of valve is to maintain a constant pressure in the cooling coil while the unit is operating.

The THERMOSTATIC EXPANSION VALVE is an improved type of expansion valve, having a sensitive bulb at the outlet of the cooling unit. As the bulb warms, some of the liquid refrigerant expands, and builds up pressure in the diaphragm power element connected with the bulb. The bellows then expands, forcing open the expansion valve needle, and liquid refrigerant flows into the cooling coil.

After the coil is cooled, the suction line begins to cool. The bulb also cools, pressure within it decreases, and the fluid within it contracts. This causes a contraction of the bellows or diaphragm; in turn, the diaphragm closes the valve needle.

The parts of this type of expansion valve are (1) the bulb; (2) the capillary tube, which transmits pressure from the bulb to the diaphragm; (3) the diaphragm power element; and (4) the expansion valve needle. This assembly functions to keep the coil supplied with refrigerant; not, as in the case of the automatic expansion valve, to maintain a specified low pressure. In fact, it does not enter at all into the regulation of pressure on the low pressure side of the system—the compressor establishes its own pressure upon the refrigerant.

This thermostatic element has to be charged with the same refrigerant as that used throughout the system. The manufacturers of these assemblies mark them with an identifying code of colors, numbers, or letters. For example, in a letter code, M indicates that the charge is methyl chloride; S indicates sulfur dioxide; and F indicates Freon 12.

Proper installation of the valve assembly is absolutely necessary for satisfactory service. Once the valve has been properly installed, operation is simple.

FLOAT CONTROL VALVES are used in the so-called flooded systems, while the dry systems utilize the automatic or the thermostatic expansion valves.

These float valves are installed on both the low pressure and high pressure sides of the flooded systems. The valve on the low pressure side allows the liquid refrigerant from the high pressure side to enter as it is required. The action of this valve is controlled by the level of the liquid in the evaporator. The float valve on the high pressure side is usually located in the receiver. This valve operates to allow the accumulated liquid to pass into the float low side until it reaches a predetermined level in the float chamber.

Evaporator

The evaporator is the cooling unit to which the liquid is led through the high-pressure line. The cooling coils

may be a bare pipe coil inside the refrigerator, or tubes inside a water cooler. In some installations, it is an air conditioning coil with a forced air blower.

Since the evaporator coil is on the low pressure side, the refrigerant enters the coil, and is subjected to a reduction in pressure because of the suction exerted by the compressor. This pressure decrease reduces the boiling point, and allows the refrigerant to boil and foam into vapor at a reduced temperature.

The evaporated refrigerant then passes through the suction line to the compressor inlet, where its pressure and temperature are indicated as it enters. The pumping action of the compressor raises the pressure before releasing the vapor to the condenser unit, and thus the cycle repeats itself.

Heat Exchangers

In your work with refrigeration systems, you may frequently come across the term "heat exchanger." Any equipment that serves to create, transfer, or utilize heat energy is a heat exchanger. The term therefore, includes boilers, radiators, condensers, oil coolers, and the condensers and evaporators of refrigeration systems. You will find, however, that the use of the term in connection with refrigeration is largely confined to the use of a specific component part, which promotes a heat exchange between the high pressure-high temperature liquid (before it reaches the expansion valve), and the low pressure-low temperature vapors leaving the evaporator on their way to the compressor.

REFRIGERANTS

Mechanical refrigeration systems use as the primary refrigerant some liquid that has a boiling point lower than water, but that, in changing from liquid to vapor at low pressures and temperatures will absorb a lesser quantity of heat. Most refrigerants commonly used in refrigerators require close-to-atmospheric pressures in the system, and thus leaking tendencies and overwork of compressors are reduced to a minimum.

Freon 12

Dichlorodifluoromethane is known variously as Freon 12, Genetron 12, or Isotron 12. In some texts, you will find it referred to as Refrigerant-12, or R-12. In Navy training courses, it is generally called Freon-12. It has a boiling point of minus 21.7 F, and would immediately boil if exposed to ordinary room temperature and atmospheric pressure. It must therefore be kept under pressure, if it is to be maintained in a liquid state; and this pressure will vary according to the ambient temperature. Its freezing point (minus 247 F), is a temperature not likely to be encountered in operating conditions.

Freon 12 has now replaced to a great extent such refrigerants as ammonia, sulfur dioxide, or methyl chloride, which because of their toxic and explosive character have caused many fatalities.

The chief advantages of this refrigerant are:

1. It is odorless and tasteless in concentrations of less than 20 percent by volume, in air.
2. It is nontoxic; but by reducing the oxygen content in a working space, it can cause suffocation.
3. It is nonexplosive and nonflammable; although it decomposes in the presence of an open flame, forming irritating and toxic gases, it will not ignite.
4. It is noncorrosive in contact with the metals that are commonly employed in refrigeration units; it will, however, corrode magnesium, and aluminum alloys that contain magnesium.
5. It is chemically stable up to at least 1000 F; above that temperature, it decomposes, forming corrosive and poisonous products.
6. It acts as a solvent, loosening and removing particles of dirt, scale, or oil within the system. However, it will eat away natural rubber gaskets, so neoprene or some other synthetic rubber must be used.
7. It mixes readily with oil, and thus simplifies the lubrication of the plant by acting as a carrier of oil to moving parts, and as an aid in returning the oil from the evaporator. This last characteristic is important, since an excess of oil in the evaporator will form an insulating film between the refrigerant and the inside surface of the evaporator.

Although Freon 12 has decided advantages over other volatile liquids that can be used as refrigerants, it is not UNQUALIFIEDLY safe. At the end of this chapter, in the section, Safety Precautions, you will find definite instructions for handling this gas so as to avoid danger to personnel and to equipment.

The disadvantages of Freon 12, from an operating standpoint, are as follows:

1. It has a low latent heat, and as a result, absorbs only about 51 Btu for every pound of refrigerant that boils off in the evaporator at 5 F, when condensing temperature is 86 F. This low latent heat necessitates the circulation of a large volume of refrigerant per ton of refrigeration.

2. In concentrations of 20 percent or more, Freon 12 will produce a phosgene gas if exposed to an open flame.

3. In its liquid form, Freon 12 can cause severe frostbite. Extra care must be taken to avoid this; since the refrigerant has no noticeable odor, leaks may escape notice.

The disadvantage of the low latent heat referred to in item 1 is better understood when you realize that the REFRIGERATION TON represents the latent heat required to melt 1 ton of ice in 24 hours. Since the amount of heat, expressed as Btu's, needed to melt a single lb of ice is 144, the melting of 2,000 lb would require 288,000 Btu's. The ton of refrigeration, however, is conventionally expressed as 12,000 Btu's per hour, or 200 Btu's per minute.

Another point to remember is that, because of the capacity of Freon 12 to absorb water, utmost caution is necessary to prevent the entrance of water (or of water-laden air) into the system. Any excessive moisture in the system can cause freeze-ups at the expansion valve. This characteristic is one that Freon 12 shares with all refrigerants whose boiling point is below 32 F.

Ammonia

At a few of the advance bases, ice making and cold storage plants use ammonia as the refrigerant. With a boiling point of minus 28 F, and a freezing point of minus 108 F (at atmospheric pressure), it provides refrigeration

at temperatures below zero, without the necessity of resorting to pressures below atmospheric, in the evaporator.

The heat absorbed in the evaporator is about 475 Btu's per lb, at 5 F, and 86 F condensing temperature; this means that a correspondingly smaller amount of refrigerant, as compared with Freon 12, will be required.

However, the dangers to personnel are its chief disadvantage. Although not classed as poisonous, ammonia has a violent effect upon the respiratory system, and the strongest concentration that can safely be breathed for any length of time is 0.35 volume of ammonia to 100 volumes of air.

In certain concentrations (1 part of ammonia to 2 parts of air), this refrigerant is flammable; when mixed with air, in the proper proportions, it is also explosive.

Methyl Chloride

At atmospheric pressure, methyl chloride has a boiling point of minus 10.6 F, and a freezing point of minus 144 F. At a temperature of 5 F in the evaporator and 86 F condenser temperature, it will be 180.7 Btu's per lb of refrigerant.

Methyl chloride in contact with water has a corrosive action. Although this refrigerant is considered nonpoisonous, the breathing of large quantities can paralyze the respiratory functions. In concentrations of as little as 8 percent by volume, it may be explosive.

Methyl chloride should NEVER be used in a refrigeration system containing aluminum or where gaskets are made of lead, because it will cause an explosion.

SELF-CONTAINED REFRIGERATION UNITS

Small units, comparable with those produced for domestic use, and the type of reach-in refrigerator (with about 15 to 20 cu ft of storage space) that is commonly used in civilian markets, are used for the storage of food that will shortly be used in preparing meals; they may also be used in hospital spaces for storage of serums and biologicals.

These domestic-type units are usually self-contained; that is, the cabinet houses both the insulated storage compartment in which the evaporator is located, and the uninsulated compartment containing the condensing unit. The latter may be hermetically sealed, or it may be semisealed, or "open type." In modern units, the condensing unit is sealed, and is located in the bottom portion of the cabinet.

However, the condensing unit may in some cases be mounted in a structure on the top of the food cabinet, with the evaporator suspended from the insulated base of the condenser housing, down into the cabinet. The structure containing the condensing unit will be removable.

The evaporator may be a double sheet with refrigerant channels stamped into the metal. The refrigerant line and the suction line between evaporator and condenser ordinarily pass up through the rear of the cabinet.

Control of the condensing unit operation is usually maintained by temperature rather than pressure controls. A selector dial, for defrosting and for raising or lowering the cabinet temperature, is connected with a temperature control mounted close to the evaporator, and with a thermal bulb in contact with the evaporator.

The small type refrigerators are completely assembled and charged at the factory, and very little work is required in installing them for use. However, they should be placed in a location where there will be adequate ventilation to carry away the heat from the condensing unit, and where there will be adequate access to service the motor, valves, and other parts, when maintenance or repair is necessary.

It is advisable to have the cabinet elevated from the floor. If the cabinet has legs, this feature is already provided for; but if it rests on its base, there should be a space of at least 3 or 4 inches, to allow for cleaning beneath it. This space will also prevent the formation of mold, and the rotting of wood or insulation. Bricks, timber, or concrete blocks can be used to raise the cabinet, but it is very important that when the cabinet is set on these blocks, it is level and secure.

Most of these refrigerators are charged at the factory, and then the refrigerant is all pumped into the receiver, to prevent any loss of the charge during shipment.

In this event, you will have to ready it for operation according to the instructions given later in this chapter, in the section, Operation and Maintenance. Units shipped in a ready-to-use condition need only the removal of compressor hold-down bolts, and a connection to an electric outlet. First set the selector dial for the desired temperature.

If it is necessary to add refrigerant, or to recharge one of these units, make sure that you use only the refrigerant specified by the manufacturer. The proper procedures to follow in charging a system are outlined later in this chapter, in the section "Operation and Maintenance."

WATER COOLERS

Cooling units that will supply personnel with drinking water at temperatures under 50 F are a necessity in almost all installations. These coolers may be self-contained units, of the bubbler or drinking fountain type; or they may be units in which the cooled water is piped from a central supply to outlets on different floors or in different buildings.

In the smaller type units, the water is cooled only when the refrigeration unit of the water cooler operates, as when water is withdrawn. In storage type units, a reserve supply of cool water is maintained. Where the storage type is installed, the required supply of cooled water to meet peak demands will always be available, whereas the capacity of an instantaneous type would be insufficient for concentrated and heavy demands.

The self-contained bubbler cooler usually has a capacity of about 3 gallons per hour, but if the unit is equipped with a heat exchanger, the capacity will rise to 5 gph. A heat exchanger makes it possible to use the water "wasted" at the bubbler to precool the warmer water entering the water cooler. Large self-contained units, equipped with 2 or more bubblers, or with 2 or more outlets at which glasses can be filled, may have a capacity anywhere from 8 gph to 25 gph.

Instant-Type Cooler

The instantaneous type of cooler may have a double coil evaporator (that is, one tube within another), or a

tank evaporator. In the double coil evaporator, the water flows through the inner coil, and the refrigerant flows in the space between inner and outer tubes. The refrigerant flow is in the direction opposite to water flow. The automatic expansion valve controlling refrigerant flow must be set at a pressure that will ensure a temperature above 32 F; a suction pressure regulating valve in the suction line helps to maintain this temperature (above 32 F) in the evaporator.

When water is withdrawn from the cooler, a compensating amount of warm water entering the water coil raises the pressure of the refrigerant in the evaporator, and the condensing unit starts to operate. When the water stops flowing, suction pressure drops to the cutout pressure control setting, and stops the condensing unit.

Storage-Type Cooler

A storage-type unit with an instantaneous cooling capacity of 3 gph, and a reserve capacity of 2 gallons, can supply a peak demand of 5 gallons within 1 hour. Some of these coolers may have reserve tanks with capacity up to several hundred gallons. Temperature controls are commonly used on these coolers—especially those with large reserve tanks—because pressure controls do not provide an accurate method of controlling temperature where loads vary widely over a period of time.

When cold water is withdrawn from a storage tank, compensating amounts of warm water enter, as in the small bubbler unit. Temperature of the tank water could rise to an unpalatably high level, depending upon the quantity of the stored water, and the quantity and temperature of the incoming warm water. An ice bank, therefore, is commonly used to cool the incoming water. An illustration of such a type of water cooler is given in figure 4-6. The ice formation around the coils gradually gives up its latent heat, to cool the incoming water.

Although the space occupied by the ice is relatively small, its cooling capacity is considerable. A single pound of ice will serve to lower the temperature of about 10 lb of water from 60 to 45 F.

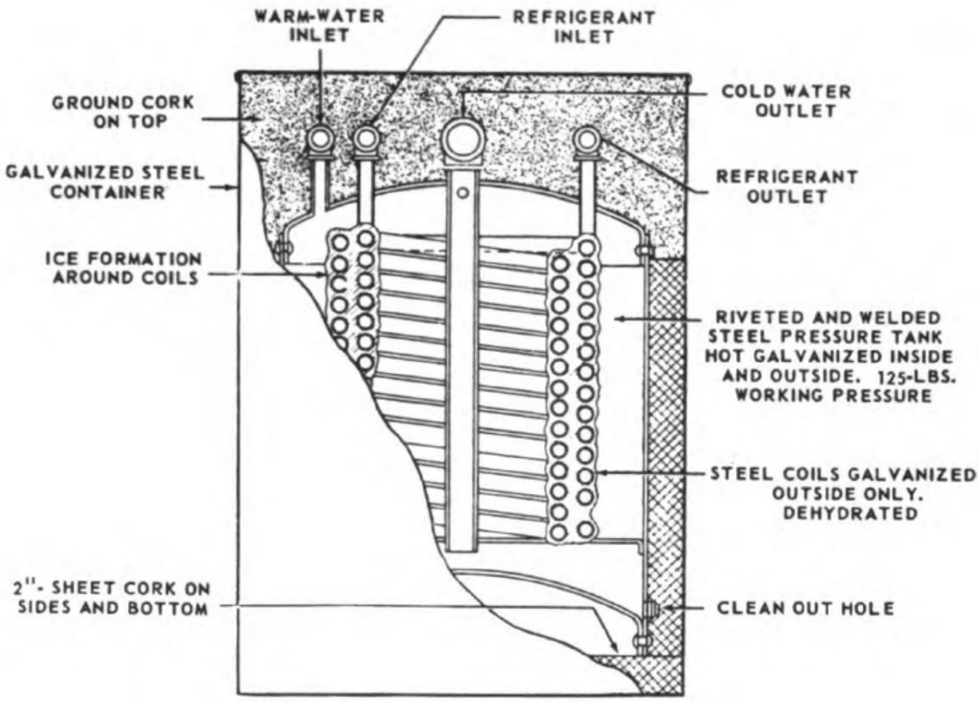


Figure 4-6.—Storage-type water cooler, with ice bank.

COLD STORAGE PLANTS

Specially constructed refrigerated spaces, or a series of walk-in coolers, can be used as storage plants for perishable supplies. Such facilities are particularly necessary for large supplies of prefrozen products, as well as for dairy products, and fresh fruits and vegetables.

No single space is likely to serve for all purposes, because of the variations in temperature that are required for various types of foodstuffs. For example, meat and meat products should be stored at about 32 F. Dairy products, and fresh fruits and vegetables, require a temperature about 3 to 5 degrees higher. Prefrozen foods, delivered in a frozen state, must be stored at temperatures from 15 F to 0 F, or lower.

Defrosting requirements also make it impossible to use a single refrigerated space for all types of food. At 32 F, the temperature required for meats, it would be extremely difficult to adjust controls for automatic defrosting, and the coolers for such spaces are fitted with a water defrost system or hot gas defrosting.

The products stored at 35 to 38 F temperatures (notably fresh fruits and vegetables) may have a very high water content, and thus require automatic defrosting. Other vegetables, requiring storage temperatures of about 40 F, may actually require a source of added heat, when prevailing outside temperatures are radically lower than freezing.

Space Requirements

Aside from the necessity of maintaining separate spaces according to the types of foodstuffs, there is the problem of how much space should be provided in order to take care of expected shipments. The following space requirements, in terms of personnel at the installation, will prove a useful guide. Remember, however, that at some bases it will not be necessary to provide for the storage of prefrozen foods.

1. Installations having fewer than 3,000 men:
   a. Cooler storage space (30 F or higher) should be at the rate of 1.2 sq ft per man.
   b. Frozen food storage space (10 F) should be 0.4 sq ft per man.
2. Installations having from 3,000 to 5,000 men:
   a. Cooler storage space should be 1.0 sq ft per man.
   b. Frozen food storage space should be 0.35 sq ft per man.
3. Installations having over 5,000 men:
   a. Cooler storage space should be 0.9 sq ft per man.
   b. Frozen food storage space should be 0.3 sq ft per man.

Units

Except in those cases where a series of small walk-in refrigerators are utilized, the cold storage plants, whether small or large, will have the following units: compressors, evaporative condensers, ventilation and heating units, and controls and instruments.

COMPRESSORS must be mounted on a firm foundation. It may be necessary to provide a concrete base and isolators, to prevent the transmission of vibrations to the rest of the building. There must be sufficient space

around the compressor to allow for air circulation for cooling, access for servicing, and enough overhead space so that it will be possible to remove the compressor head and discharge valve plates. Adequate lighting must also be provided.

EVAPORATIVE CONDENSERS must be located adjacent to an outside wall, so that they can utilize outside air as a cooling medium. If they are placed outside instead of inside the building, they must be set on piers, or on a solid level concrete foundation. If they are installed indoors, they must be level, and set on a floor or foundation capable of supporting their weight. Enough space must be left on all sides to permit proper air circulation, and access for cleaning and servicing.

A short air-inlet duct leading to the inlet connection of the condenser provides the necessary passage for the outside air. The diameter of the duct must not be less than that of the opening into the unit. The opening to the outside air must be screened to prevent trash from entering.

Discharge outlets must be positioned so as to direct the air away from the inlet connection; otherwise, the warm, moist air in the discharge outlet may be circuited back to the inlet. Discharge ducts installed through the roof of the storage space should terminate in a gooseneck, to prevent rain from entering the duct.

Motors, drives, and electric switches that are exposed to the weather must be protected by metal hoods or guards.

VENTILATION must be provided for the machine room, else the operation of motor and compressor will soon cause a rise in the space temperature. Ventilation is also necessary to remove refrigerant vapors in case leaks develop.

HEATING is required in storage spaces, in cold climates, to prevent the freezing of products, and also to prevent condensation of the refrigerant gas in any part of the system except the condenser. Heating of the space is needed where a pressurestat control is in use, because if the space temperature drops below the evaporator temperature, operating difficulties will develop.

CONTROLS, SWITCHES, GAGES, and other instruments should be mounted on a panel. The identification

of these various control devices should be stencilled beneath them, or else indicated by a nameplate. It need hardly be pointed out that the panel must be conveniently located and well lighted.

Temperature Controls

The device most frequently used for space temperature control is a room thermostat electrically connected to a solenoid valve in the liquid line. With this combination, a suction pressure control is used to start and stop the compressor. Temperature recorders should be placed on or near the control panel, with feeler or thermal elements located in the different storage spaces. In a multiple system with rooms at various temperatures, an adjustable back-pressure regulating valve can be installed in the suction line from the high temperature rooms.

The flow of refrigerant to individual unit coolers or plate coils is controlled by thermostatic expansion valves.

Where a cold storage plant includes a room that must be maintained at 10 F (for frozen products), a separate compressor is usually needed. The compressor for this 10 F space is equipped with low and high pressurestats, and is started and stopped by a room thermostat. No other room control devices are necessary.

Operating and Maintenance Procedures

Operators at work in the machine room of a cold storage plant must be constantly alert to unusual noises, heavy vibration, hot motors, loose belts, and to slow starting of the unit.

DEFROSTING of unit coolers is best done by water defrosting. If faucet water is too cold to bring about a rapid thaw, hot water must be used, but in no case should the temperature of water sprayed over the coils be above 100 F.

In the 10 F room, defrost the plate coils by scraping and brushing; it is best to use wooden paddles for this operation, to avoid injuring the coils. Never let frost accumulate to the point where air passages are blocked.

In all cold storage rooms, avoid unnecessary or prolonged opening of the doors.

Condenser spray nozzles and strainers should be cleaned weekly. Scrub the condenser coils and collecting pan monthly. If chemicals must be used in water treatment, see that they are replenished daily. Where a plant is equipped with receiver sight gages, check the liquid refrigerant level at least once each shift, after the compressor has been shut down.

If mold occurs, remove the stored products to another storage space, turn off the refrigerant supply, and spray walls and ceiling with a strong solution of trisodium phosphate (1 lb to each gal of water). After the sprayed surfaces have dried, rinse them with clean water, and let them thoroughly dry again. Scrub the floor with old brooms or brushes, then rinse with clear water.

Since mold growth is accelerated by pockets of dead air, check the air circulation in the affected space. It may be necessary to reposition air outlet louvers. Painting the walls and ceilings with a standard refrigerator enamel (but not with cold water paints or with paints containing linseed oil) will help to prevent future growth of mold.

PREVENTIVE MAINTENANCE is better than waiting for an adverse condition to develop, and then correcting it. Make these maintenance checks periodically; schedule them so that all items receive an inspection during some specified period, either a month or a week. Necessary repairs are more easily accomplished in this way than if they were all made at one time.

If these inspections disclose evidence of rust, you will have to rely upon constant cleaning, and the application of paint or varnish to the rusting surfaces, as the only practicable remedy. Most of the inhibitors commonly used in brine sprays for rust control are harmful to food products. It will only be safe to use a sodium chloride brine solution in brine spray units serving storage rooms for perishable food. Since a certain amount of brine mist is carried over into food storage spaces with air from the spray unit, inhibitors cannot be used.

OPERATING LOGS are a very important factor in maintenance and repair. Conditions recorded in the log provide guidance for the supervisor, and for succeeding operators.

Items that should be recorded in the operating log include the following: temperature recordings; receipt

of large shipments of foodstuffs; unusual conditions that could affect plant operation; necessary repairs accomplished; items covered in preventive maintenance inspection.

REFRIGERATOR CONTROL SYSTEMS

The types of motors used to drive refrigerators may be hermetic (sealed in), or open. Hermetic motors are installed inside the compressor dome, and drive the compressor directly. Open motors drive the compressor either directly, or by means of a belt.

The electrical systems of late-model refrigerators comprise motor, motor control, starting switch, and cabinet light and switch. There may also be a condenser motor fan and an ultraviolet-ray lamp.

Any recent book on refrigeration will show wiring diagrams of the types of units in common use. If you have studied the training course, *Basic Electricity,* NavPers 10086, these diagrams should be understandable. However, the electrical aspects of servicing a unit require the aid of an electrician, except for such adjustments as are specifically mentioned in this chapter.

REFRIGERANT CONTROLS

We have already seen how the automatic expansion valve responds to pressure changes, and the thermostatic expansion valve responds to a rise of temperature within the thermal bulb. These valves are equipped with adjusting screws that make it possible for the unit operator to adjust pressure, or to raise or lower superheat.

You remember that as pressure decreases on the low pressure side of an automatic expansion valve, the valve opens to allow more refrigerant to enter the evaporator. In other words, the tension of the adjusting spring, exerted against the diaphragm, is greater than the pressure within the diaphragm. As soon as the pressure within the diaphragm becomes great enough to overcome spring tension, the valve closes.

Adjustment can be made by turning the adjusting screw counterclockwise to lower pressure, and clockwise to increase it.

In the thermostatic expansion valve, increase in temperature causes the liquid in the bulb to expand. The resulting increase in pressure, transmitted to the diaphragm, counteracts the spring tension, and causes the needle valve to open after the compressor starts and lowers the evaporator pressure. As temperature (and pressure) in the bulb decreases, the spring tension becomes greater than the pressure of the fluid on the diaphragm, and the needle valve closes after the compressor stops.

Adjustment can be made by turning the screw counterclockwise to lower the superheat, and clockwise to raise it. Superheat should be set according to the manufacturer's instructions for the equipment; if no instructions are available, Navy specifications require that the superheat be set somewhere between 4 and 12 F. Superheat readings are derived by subtracting evaporation temperatures from tail coil temperatures. Note: Never attempt to adjust expansion valves except as a last resort and after all other probable troubles have been eliminated.

Motor Controls

Automatic refrigeration provides correct temperatures with a minimum of attention from the operator of the unit. One method of ensuring the proper temperature is to stop the motor when the correct temperature is reached. The second method is to stop the flow of refrigerant when the correct temperature is reached. This latter method is the one generally used in multiple commercial systems, but it is seldom used for single refrigerating units.

The temperature of the refrigeration unit must be maintained within a certain predetermined range. If you allow the temperature to fall below the low limit, the stored food will spoil by slow freezing. Accordingly, some type of motor control must always be provided to cut out the unit when low temperature limit is reached, and to cut it in when unit temperature again rises.

PRESSURE AND THERMOSTATIC CONTROLS may be any device which will change position in response to a temperature or pressure variation. The one most

commonly employed is the diaphragm device. The pressure changes may come either from the confined liquid, or from the low pressure side of the system. When the system pressure is great enough to offset atmospheric pressure plus any spring pressure present, the resulting movement of the bellows closes a switch, and allows current to flow to the motor. When temperatures and pressures decrease, the diaphragm will collapse, and the switch will open and cut off current flow.

TEMPERATURE CONTROL DIFFERENTIAL AND RANGE ADJUSTMENT are also provided on modern units, since it may sometimes be necessary to adjust the temperature limits themselves, as well as to maintain the predetermined limits.

The range adjustment involves raising or lowering both limits by the same amount. To obtain a setting that is either warmer or colder than the existing one, it is only necessary to turn an indicated knob, or a calibrated dial. The adjustable force may be weight, although more usually it is a spiral spring. This force acts upon the diaphragm whether the thermostatic switch that controls current flow is in the cut-in or the cut-out position.

An adjustment that establishes a different range between cut-in and cut-out temperatures is a differential adjustment. It involves a change in the number of degrees between the high and low points—a change that does not take place in a simple range adjustment. However, the differential adjustment cannot take place without a range adjustment also being made, although a range adjustment can be made without a differential adjustment being involved.

What the differential adjustment actually does is to modify the cycling time. This is not an adjustment that can safely be made by every unit operator. Never attempt to change the cycling interval of a system unless you thoroughly understand what you are doing.

Overload Protection

Essentially, the efficiency of a refrigeration unit is determined by the degree to which heat can be removed from the food stored in the cabinets. This heat usage, or service load, is affected not only by the produce to be

cooled, and the volume of this produce, but also by three factors having to do with changes of air in the cabinet. These factors are as follows:

1. Temperature difference between exterior and interior of the cabinet.
2. Air changes in cabinet.
3. Lights and motors used in the unit.

Refrigerators must be protected against too much current draw, and against overheating. It is also necessary to guard against overloading the cabinet, since if this occurs, little or no refrigeration will take place. The doors to a unit must not be opened unnecessarily, nor left open needlessly.

Defrosting

The need for periodic defrosting arises from the fact that moisture from the air freezes on the surface of the cooling coil. This layer of frost acts as an obstruction to heat flow. The rate at which this frost layer builds up is accelerated by such factors as frequent opening of the cabinet door, humidity of the outside air, and the moisture content of the product stored.

Many of the refrigerator models installed recently, especially those containing frozen food units, have automatic defrosting controls. Defrosting time is determined by one of the following automatic devices:

1. An electric clock which defrosts the unit at specified intervals of time.
2. A defrosting device which defrosts the unit on the basis of number of times the refrigerator is opened.
3. A clock which runs only when the unit is on current, and which defrosts after a specified running time.

In warehouses, and in other large refrigeration units, the defrosting operation must be started manually. In systems where a defrosting pump is used, put the selector switch at OFF, stop the unit, and remove the condensate drain cap. Place the lower pump hose in a bucket of water having a temperature of from 100 to 120 F. When the pump is operated, water from the headers will spray on the evaporator. After about 10 minutes, and after making sure that the unit is thoroughly drained, you can

replace the hose, recap the condensate drain, start the unit, and turn the selector switch to AUTOMATIC.

If you are dealing with an old model refrigerator, you will have to figure out the defrosting method, especially if the manufacturer's instructions are no longer available. The older types, manufactured 25 years ago, are equipped with manual defrosting switches. Others are equipped with semiautomatic controls; the defrosting period starts when the indicated button is pushed, but the unit automatically returns to operation when the defrosting is accomplished.

OPERATION AND MAINTENANCE OF REFRIGERATORS

The first step to learn in the operation and care of refrigerating units is to keep the refrigerator, and the areas surrounding it, scrupulously clean. Small refrigerators must be cleaned every week, and always after defrosting. Cold storage rooms should be thoroughly cleaned at least once every 3 months. However, the units should never be hosed down, since water may seep into the insulation and cause it to deteriorate. Wash ice trays, food shelves, and interior walls with soap and warm water, and rinse off with a mild solution of baking soda and water (about 1 tablespoonful of soda to 4 quarts of water). Wipe the door gaskets daily with a damp cloth, to remove grease or oil.

When a small unit is received with the refrigerant pumped down, it should be started by first installing service gages, opening service valves on the condensing unit, testing for refrigerant leaks, and then starting the compressor. These units will probably be accompanied by the manufacturer's instruction book, and you should follow the procedures outlined there.

To start the compressor, close the manual switch, set the selector dial, and plug the cord into the power supply outlet. Since the receiver stop valve is still closed, the compound gage should drop rapidly, while the pressure gage shows a slow increase in discharge pressure.

If the refrigerant is Freon 12, partly close the suction service valve as soon as suction pressure drops to 35 percent, and open the receiver stop valve. Over an

hour's time, gradually open the suction service valve, watching to see that suction pressure does not rise above 35 psi.

Check the refrigerant charge, to see if any refrigerant should be added to the system. Start the unit and after it has operated for a while, check the temperatures at the following points: compressor, condenser, liquid line, evaporator, and suction line. At the same time, listen to the sound that the expansion valve is making. All of these checks will help the operator to know whether there is sufficient refrigerant to make the expansion valve operate in accordance with the instruction provided.

You can then check the oil level of the compressor, and check belt alignment and tension.

Before opening the electrical switch box to put the unit into operation, wipe the unit to remove any oil or dust that has collected.

To ensure the proper operation and maintenance of any refrigeration unit, there should be a systematic schedule of inspections, tests, and checks. The best control is to maintain a daily operating log, upon which hourly recordings are made of machine room temperature; compressor speed (where variable speed compressor operation is possible); gage and temperature readings in the suction line and the discharge line of the compressor; gage and temperature readings in the condenser; temperature of the liquid refrigerant; and the temperatures of the various refrigerating spaces. A form such as that illustrated in figure 4-7 will be adequate.

Machine room temperature, water supply in the condenser, and compressor rpm represent conditions; the remaining gage and temperature readings represent results. With this type of operating log as a guide, it is often possible to determine what corrective measures are required when the plant fails to operate properly.

The principal steps necessary to put a unit into operation are: testing for level; purging the system of air; installing the service gages; testing for leaks; charging with refrigerant; making an over-all check of the equipment; checking the oil level; checking the control valves; and checking the motor oil valves.

Besides the instruction books issued by the manufacturers of refrigeration equipment, it would be wise to

COMPRESSOR NO. 2 DATE 6/6/58

TIME	MACH. ROOM TEMP (°F)	COMPR. SPEED R.P.M.	COMPRESSOR: F-12 SUCTION LBS. GAGE	COMPRESSOR: F-12 SUCTION °F	COMPRESSOR: F-12 DISCHARGE LBS. GAGE	COMPRESSOR: F-12 DISCHARGE °F	COMPRESSOR: OIL LBS. GAGE	COMPRESSOR: OIL BULLS EYE LEVEL	COMPRESSOR: CRANKCASE REL TEMP.	COMPRESSOR: CRANKCASE NOISE	CONDENSER: WATER SUPPLY LBS. GAGE	CONDENSER: WATER SUPPLY °F	CONDENSER: DISCH °F	F-12 LIQUID °F	F-12 LIQUID CONDITION AT SIGHT FLOW	WEATHER: DRY BULB °F	WEATHER: WET BULB °F	REFRIGERATED SPACES: ICE SET °F	COMPARTMENT TEMPERATURE (°F) MEAT RM.	THAW RM.	VEG. RM.	DAIRY RM.	REMARKS
0100	88	540	7	38	95	162	27	OK	WARM	OK	24	60	80	82	OK	82	73	7	17	40	34	32	
0200	89	540	4	46	95	162	25	OK	WARM	OK	24	60	82	82	OK	82	73	9	15	38	40	32	
0300	89	540	2	56	95	194	22	OK	WARM	OK	24	58	80	86	VAPOR BUBBLES	80	72	11	19	42	42	36	
0400	88	543	3	-4	85	143	24	LOW	COLD	KNOCK	24	58	80	76	OK	80	70	10	14				
		540	12	35	95	153	32	LOW	WARM	OK	24	60	80										
2200	93	540	10	30	106	162	31	OK	WARM	OK	24	58	90	91	OK	84	70	11	23	41	41	33	
2300	93	540	7	30	120	168	28	OK	WARM	OK	24	58	90	93	OK	84	72.5	10	18	40	39	32	
2400	93	540	6	30	113	152	26	OK	WARM	OK	24	58	90	92	OK	84	71	7	16	39	38	31	

Figure 4-7.—Daily operating log for a refrigeration unit.

provide yourself with a copy of *Machinist's Mate 1 and C,* NavPers 10525. Chapter 11 of this training course contains a great deal of helpful information, as well as a trouble-diagnosis chart. *Refrigeration, Air Conditioning, Evaporative (Desert) Cooling and Ventilation, War Department Technical Manual 5-670,* is another excellent guide to the proper operation and maintenance of refrigerating and air conditioning equipment. This text, also, has a very practical and complete trouble-shooting chart.

Testing for Levelness

Before starting up any new refrigeration installations, use a spirit level to test the levelness of cabinets, condensing units, and evaporative condensers. Where necessary, use shims, washers, or anchor plates, to ensure that the equipment is level.

Purging Air

As much vacuum as possible must be drawn on all new or overhauled installations, in order to remove air and moisture from the system.

A separate vacuum pump must be used. If none is available, you can improvise one by using a spare 1/3 hp compressor connected to a 1/3 or 1/4 hp motor. Connect the suction side of the vacuum pump to the suction service valve of the refrigerator compressor, and turn the valve to the halfway position, so that vacuum is drawn from compressor crankcase and suction line back through the evaporator, expansion valve and liquid line, to the receiver stop valve (king valve) if closed. If the receiver stop valve, condenser stop valve, and discharge service valve are open, there will be complete evacuation; the vacuum pump will draw back through the receiver and condenser to the compressor discharge valve plate in the head of the compressor.

Connect a length of copper tubing to the discharge outlet of the vacuum pump. Operate the pump until you have a vacuum of at least 25 inches. Then submerge the other end of the tubing in a bottle of clean compressor oil; the end should be 2 or 3 inches below the surface of the oil. Continue to operate the vacuum pump. When

bubbles cease to appear in the oil, you have obtained a deep vacuum. Maintain this for 5 minutes, then stop the pump.

If there are leaks in the system, air will enter under the force of atmospheric pressure. Allow 15 minutes, then start the vacuum pump again. If bubbles now appear in the oil in which the tubing is submerged, examine and tighten the joints in the line, including the line from the suction service valve to the vacuum pump; then repeat the test. When no bubbles appear the system is ready for charging. If the bubbles persist, the system must be tested, as described later in the section, Testing for Leaks.

Purging the air from a system already in operation, when an accumulation of moisture must be eliminated, is done as follows:

1. Close down the system.
2. Drain off the refrigerant and air.
3. Circulate heated air (240 F) through the system for several hours.
4. Evacuate the remaining moisture, by using a vacuum pump, with a vacuum indicator in the pump suction line.
5. Connect the pump suction line to the refrigeration system charging connection; close the refrigerant circuit to atmosphere, and open the charging inlet.
6. When most of the moisture has been evacuated, the indicator will show a drop in temperature. When the temperature is 35 F, open the system at the point farthest from the pump, and draw in air.
7. Close off this opening, and evacuate again until the temperature drops to 35 F.

At this point, the evacuation is complete, and you can close the charging valve, and stop the vacuum pump.

Installing Service Gages

Service gages come in the form of a gage manifold, with the necessary valves and connections. The pressure gage is on one side, and the compound gage on the other. To install these gages, proceed as follows:

1. Remove the cap of the compressor suction service valve, and turn the valve stem outward, as far as it will

go, to its back seat. This closes off the service gage port from the compressor crankcase and suction line.

2. Remove the plug from the gage port, and replace it with a flared tube connector fitting.

3. Connect the flared tube fitting with the flexible tube on the 30-inch vacuum, 150-lb compound gage side of the manifold.

4. Move the valve stem of the suction service valve inward, off the back seat, about 1/2 turn, and tighten the gland nut.

5. Crack the valve on the compound gage side of the manifold, to allow air in the flexible line to escape through the service drum connection.

6. Repeat the same procedures, to connect the pressure gage side of the gage manifold to the service port of the DISCHARGE service valve.

To open the condenser service valve (if installed), remove the valve cap, and then turn the valve stem outward 8 or 10 turns, or until it back seats. Tighten the gland nut, and replace the valve cap, pulling it up until it just compresses the gasket. Next, slightly open the compressor discharge service valve. Never start a compressor with the discharge service valve closed.

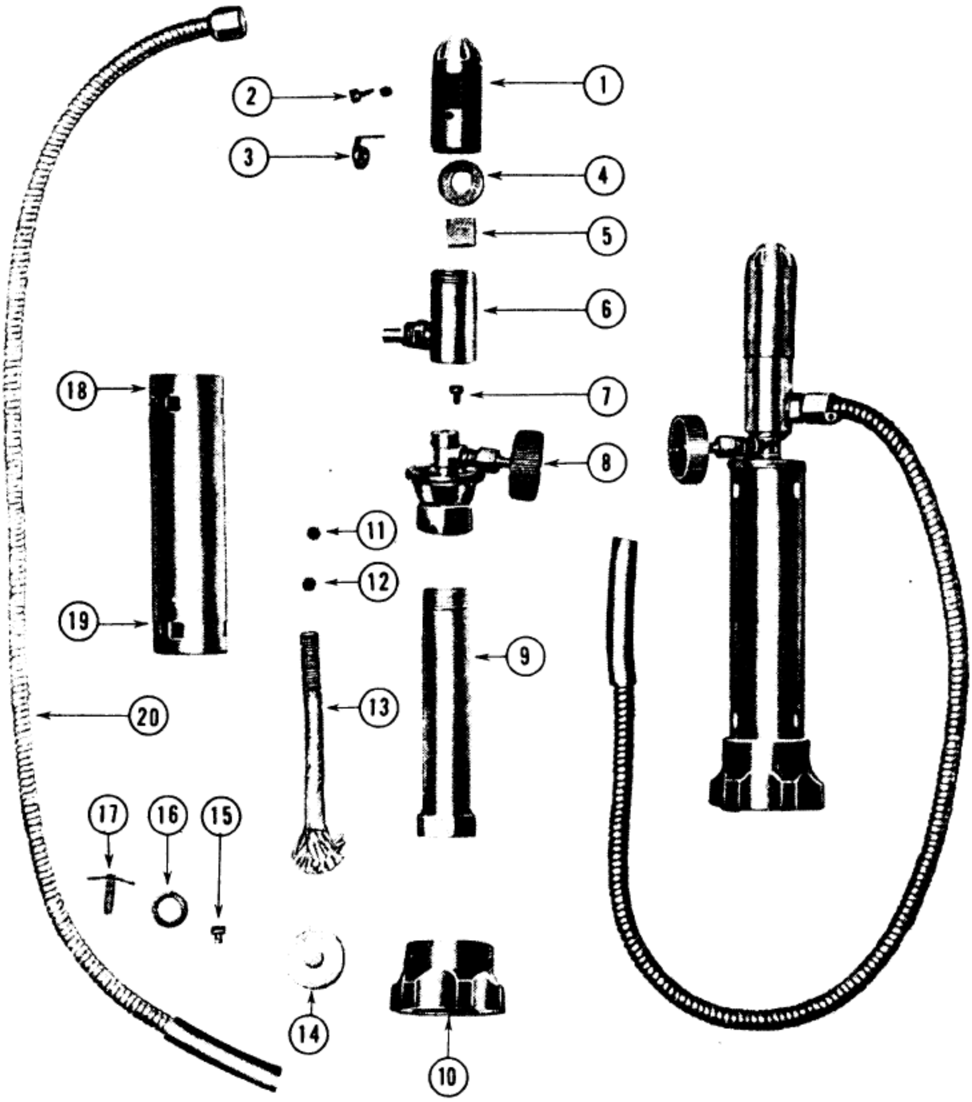
Open the receiver stop (or king) valve by removing the cap and cracking the valve until the compound gage reads 50 psi. Then close the valve, and tighten the gland nut.

Testing for Leaks

Small leaks in a system cannot be located, regardless of the method of detection, unless the pressure inside the system is from 40 to 50 psi. There is always sufficient pressure in the high pressure side of the system, but on the low side, pressures are sometimes only slightly above zero psig. To test for leaks, therefore, you must increase pressure on the suction side by bypassing discharge pressure from the condenser to the suction side, through the service gage manifold, when the compressor is shut down.

If you are going to test for leaks in a system using methyl chloride as refrigerant, make sure that the working space is well ventilated, before you light off the torch. Remember, this vapor is highly flammable.

The halide torch, illustrated in figure 4-8, is the best device for testing for leaks in Freon 12 or methyl chloride systems. Keep the flame of the torch as low as possible, so that even a small refrigerant leak will cause the flame to change color. The torch should show a blue flame when lighted, and this will change to a greenish flame when it



1. CHIMNEY
2. FLAME RING SCREW AND NUT
3. FLAME RING
4. CLAMP WASHER
5. CHROMEL SCREEN
6. MIXING VENTURI
7. FUEL JET
8. VALVE STEM AND WHEEL ASSEMBLY, GENERATOR VALVE BODY ONLY, AND BRASS PRIMING CUP
9. FUEL TANK
10. BASE CAP
11. FINE WICK SCREEN
12. COARSE WICK SCREEN
13. WICK ASSEMBLY
14. BRASS DISK
15. EXTRA FUEL JET
16. EXTRA BASE CAP WASHER
17. JET CLEANING WIRE
18. COMPOSITION CASE
19. CASE SETSCREW
20. METAL SAMPLING TUBE ONLY, SAMPLING TUBE NUT, AND SAMPLING TUBE FERRULE

Figure 4-8.—Halide torch, alcohol type.

contacts a refrigerant leak. If it burns with a greenish flame when lighted, there is refrigerant in the air. Go over all joints, especially flared tube nuts, fittings, sweat connections, and gasketed joints.

A sulfur candle is used to test for ammonia leaks. When its flame comes in contact with ammonia fumes, a small white cloud is formed.

A soap and water solution can be used to test any system. It can be applied with a soft brush, but you must wait until all bubbles have disappeared from the solution. Then, if bubbles appear after it has been brushed on to the joints or tubing where leakage is suspected, you know that they are caused by the escaping refrigerant.

Charging With Refrigerant

If a reserve supply of refrigerant is maintained in the receiver, small leaks will not cause a shortage. However, if the system does not have a full operating charge, or if it is a new installation delivered with only a holding charge (that is, enough refrigerant to maintain pressure, but not enough to charge the system), refrigerant must be added.

It is a simple matter to check on the liquid level on systems where liquid level indicators are installed. On systems not so equipped, you will find it advisable to install a bull's-eye fitting, or sight glass, in the liquid line, preferably near the receiver.

To install a sight glass, close the receiver service valve, and operate the condensing unit, with thermostat or pressure control blocked out. When the suction gage reads zero psi, stop the condensing unit. Disconnect the liquid line from the receiver service valve, and connect it to the sight glass. Then use a short tube and fitting to connect the sight glass to the receiver service valve. If there is not enough liquid refrigerant in the line, bubbles will form, and can be seen as they pass through the sight glass.

In adding refrigerant to the system, first make sure that you have the right refrigerant cylinder. Freon containers are orange; methyl chloride containers are gray with a red top; ammonia cylinders are black with a brown top. Weigh the cylinder and record its weight. Keep it

upright while using it; if it tips, refrigerant may be fed into the compressor, causing broken compressor valves or other damage.

Connect the cylinder outlet and the bottom center connection of the service gage manifold with a 3-ft length of tubing; leave the manifold connection loose at first. Open the cylinder valve, and when air is purged out of the 3-ft tube, tighten the connection at the gage manifold.

While the refrigerant is being charged, both the compound and the pressure gage sides of the manifold must be connected, to indicate suction and discharge pressures.

As the refrigerant gas is discharged from the cylinder, both the temperature and the pressure in the cylinder will drop. Eventually the cylinder may frost, and delivery pressure may drop so low that it takes an undue amount of time to recharge the refrigeration system. The safe way of maintaining the cylinder temperature and pressure is to set it, still upright, in a pail of hot water (120 to 150 F).

During this recharging, you must watch the compound gage, and if it rises above proper charging temperature, or pull-down pressure, you must lift the gas cylinder out of the hot water until pressure again drops too low. You must also keep checking the system for liquid level; but first turn off the gas cylinder outlet valve, and lift the cylinder out of the hot water. When the refrigerant charge reaches normal level, close the cylinder valve, then close the valve on the gage manifold, and remove the connecting tube.

Checking Equipment

When putting new equipment into operation, and even when starting up a system that has been out of operation for a few hours, you should give the entire system a checkover. Use a straightedge to ensure that compressor and motor PULLEYS ARE IN LINE. Check the belt tension. Remember that if there are 2 or more V-belts on one drive, they must have identical tension; otherwise, one will carry more than its share of the load, will overheat, and wear out. When one V-belt of a multiple set must be replaced, change the whole set, in order to ensure uniformity of length and tension.

Before STARTING THE COMPRESSOR MOTOR, see that the compressor discharge service valve is open, and the gage manifold properly connected. Check the oil wells of open motors. When you start up the system, you may be starting with a warm evaporator in a warm refrigerator; this could result in overloading of the condensing unit motor. You might throttle your suction valve for a few minutes, until evaporator temperature drops to 35 F.

After starting the compressor, watch the GAGES on the gage manifold. The pressure gage should rise slowly, and the compound gage drop rapidly, since the receiver service valve is still closed. When suction pressure reads 35 psi for a Freon 12 system (25 psi for methyl chloride), open the receiver service valve and close the suction service valve enough to maintain the pressure at this level.

OIL from the compressor crankcase mixes readily with Freon 12, and is carried through the system. The amount of oil in transit through the system depends upon the amount of refrigerant, size and temperature of the evaporator, and velocity of the refrigerant vapor through the evaporator coil and the suction line. It does not depend upon the amount of oil in the crankcase. Where the crankcase is small, and the amount of oil in transit is large, it is quite possible that the oil left in the crankcase is inadequate to lubricate the compressor.

There is no accurate way of estimating how much oil will travel with the refrigerant, so the feasible method is to watch the crankcase oil level, and add as much as is necessary. After the system reaches equilibrium, the oil returns to the compressor on the suction side as fast as it leaves on the discharge side. It is good procedure to check the oil level 2 hours after the system is started, and then check again on the following day.

The DEVICES CONTROLLING REFRIGERANT FLOW must also be checked. These controls are the expansion valves, the float valves, and the capillary tubes. The automatic expansion valve is a constant outlet pressure valve, and the correct setting is that pressure which corresponds to evaporator pressure when the refrigerator is at desired temperature and the evaporator is fully active.

This pressure, of course, depends upon the refrigerant used, and the size of the evaporator. In small, domestic units, automatic expansion valves are set to hold evaporator pressures at from 14 to 18 psi for Freon 12 systems, and from 8 to 11 psi for methyl chloride systems.

The thermostatic expansion valve, on the other hand, is a constant superheat valve. Do not set this valve until the refrigerator has reached the normal operating temperature range, and has gone several times through the operating cycle. Then adjust the valve so as to keep the evaporator fully active during the last three-quarters of the condensing unit running cycle.

Float valves, both high and low side, are actually non-adjustable. The high-side float, however, operates on a balanced charge, and you know that it is correctly operating if, at the end of the running period, the evaporator is fully frosted. As regards the low-side float, the amount of charge is not critical, since the function of the float is to maintain the level of the refrigerant in the evaporator.

The capillary tube is similar to the high-side float valve, except that it continues to pass refrigerant into the evaporator even after the condensing unit stops. The capillary tube is functioning properly if the evaporator is completely frosted at the end of the running period.

LOW PRESSURE CONTROL is set to cut in at 28.5 psi, corresponding to a temperature of 30 F. The usual temperature range for a Freon 12 system that will maintain an average evaporator temperature of 20 F is from 22 F to 18 F. The pressure corresponding to 22 F is 22.5 psi, but a margin of 6 psi has to be allowed because the expansion valve requires a 6 psi drop in evaporator pressure before it opens.

To operate a Freon 12 system on a defrosting cycle, set the low pressure control to cut out the condensing unit at 19.7 psi (corresponding to 18 F), and to cut it in at 33.5 psi (36 F). A pressure of 33.5 psi assures defrosting of the corners and bottom of the evaporator before it starts up. Once the condensing unit starts, evaporator pressure will quickly drop to 22.5 psi, and an average operating pressure of 21 psi (20 F) will be maintained.

Radio Interference

Sometimes a slight amount of radio interference occurs when a refrigerator stops. This situation can usually be remedied by grounding the motor frame, perhaps to a water pipe. However, the occurrence of excessive interference whenever the unit is started or stopped indicates that there is a loose connection, or else some defect in the starter mechanism of the motor. If the latter is the case, it may be necessary to have an electrician look over the motor, to determine the exact cause.

It is possible for static charges to be built up in belt-driven compressors, and as the static electricity discharges, to cause radio interference. To eliminate this interference, the motor and compressor should be grounded together.

TROUBLE SHOOTING

Faulty operation of any refrigeration or air conditioning system is indicated by very definite symptoms. These symptoms may be caused by one or more incorrect conditions which must be eliminated in a step by step process of corrective measures. The following chart of symptoms, their causes and correctives, will assist the Utilities Man in correcting faulty operation quickly and efficiently.

TROUBLE DIAGNOSIS CHART

WATER COOLED CONDENSERS

Symptom or difficulty	Condition may be due to	Correction
High head pressure	Air or noncondensable gas in system	Purge air from condenser.
	Inlet water warm or insufficient water flowing through condenser.	Check for obstruction in condenser water supply strainer or partially closed valve.
		Check water regulating valve.

Sympton or difficulty	Condition may be due to	Correction
	Too much gas in condenser.	Clean condenser water tubing.
	Condenser clogged or limed.	Draw off refrigerant into service drum.
	Too much refrigerant in system. (Condenser tubes submerged in liquid refrigerant.)	Vent condenser (water side).
Low head pressure	Too much water flowing thru condenser.	Regulate water inlet valve.
	Water too cold. Hand operated valve, unthrottled.	Reduce quantity of water as above.
	Liquid refrigerant flooding back from evaporator.	Change expansion valve adjustment, examine fastening of thermal bulb.
	Leaky suction or discharge valves.	Test with gages. If leaking, replace.
	Shortage of refrigerant.	Add refrigerant.
High suction pressure	Overfeeding of expansion valve.	Regulate expansion, check bulb attachment.
	Leaky suction valve.	Remove head, examine valve disks, or rings. Replace if worn.
	Discharge valves leak slightly.	Examine valves, replace if necessary.
Low suction pressure	Restricted liquid line and expansion valve or suction screens.	Pump down, remove, examine, and clean screens.
	Insufficient gas in system.	Check for gas shortage.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.

Sympton or difficulty	Condition may be due to	Correction
	Improper adjustment of expansion valves.	Adjust valve to give more flow.
	Stuck or frozen expansion valve.	Tap or thaw expansion valve as necessary.
Compressor short cycles on high pressure output	Insufficient water flowing through condenser; clogged condenser.	Determine if water has been turned off. Adjust water regulating valve. Check for limed condenser or obstruction in water strainer.
	High pressure cutout incorrectly set.	Check setting of high pressure cutout.
	System overcharged with refrigerant.	High pressure cutout may be tripping due to insufficient condenser capacity because condenser tubes are submerged. Draw off refrigerant.
	(See High Head Pressure.)	
Compressor short cycles on low pressure cutout	Coils in refrigerators clogged with frost.	Defrost coils.
	Liquid suction or expansion valve screens dirty.	Pump down and clean screens.
	Thermal bulb on expansion valve has lost its charge. (See low suction pressure, above.)	Detach thermal bulb, hold in the palm of one hand, gripping the suction line with the other hand. If flooding through is observed, the bulb has not lost its charge. If not flooding through, replace expansion valve.

Symptom or difficulty	Condition may be due to	Correction
Compressor runs continuously	Improper functioning of the low pressure control switch.	Adjust or replace switch.
	Overloaded compressor.	Start additional compressor if system is arranged for isolating loads carried by more than one unit in operation.
	Shortage of refrigerant (with temperature control).	Test refrigerant, if insufficient, add proper amount necessary. Test for leaks.
	Suction or discharge valves leak badly	Test valves, if leaking, remove head of compressor and repair or replace.
	Head gasket blown between cylinders.	Replace gasket.
Compressor noisy	Vibration because not bolted to foundation rigidly.	Bolt down rigidly.
	Too much oil in circulation causing hydraulic knock.	Check oil level.
	Slugging due to flooding back of refrigerant.	Expansion valve open too wide; close. Thermal bulb incorrectly positioned.
	Wear of parts such as piston pins, eccentrics, etc.	Determine location of cause. Repair or replace compressor.
Oil leaves crankcase	Too much refrigerant flooding back.	Readjust expansion valves. Check bulb attachment.
	Leaking piston rings or worn cylinder.	Replace rings or compressor, or rebore and refit.

Symptom or difficulty	Condition may be due to	Correction
	On starting, suction pressure drop too rapid.	Short cycle compressor on starting.
Oil does not return to crankcase	Expansion valve not flooding coil.	Adjust to flood coil.
	Valve in oil return line closed or stuck shut.	Open.
Compressor will not start	Overload tripped; fuses blown.	Reset overload, replace fuses and examine for cause or condition.
	Switch out.	Throw in switch.
	No charge of refrigerant in system operated by a low pressure control switch.	Recharge.
	Solenoid valve on liquid line closed.	Replace or repair.
	No voltage or low voltage.	Check for voltage.
Water valve chatters	Water pressure too high.	Reduce water pressure.
Cylinders and crankcase sweating	Too much oil in circulation. Liquid refrigerant in circulation.	Examine for conditions of refrigerant and oil charge. Correct the condition.
Crankcase frosting	Liquid refrigerant returning to compressor.	Adjust expansion valve.

AIR COOLED CONDENSERS

Symptom or difficulty	Condition may be due to	Correction
High head pressure	Air flow to condenser restricted.	Remove loose articles that would tend to restrict the flow of air.
	Air or noncondensable gas in system.	Purge air from system.

Symptom or difficulty	Condition may be due to	Correction
	Overcharge of refrigerant.	Draw off refrigerant into service drum.
Low head pressure	Liquid refrigerant flooding back from evaporator.	Change expansion valve adjustment, examine fastening of thermal bulb.
	Leaky suction or discharge valve.	Test with gage, if leaking, replace.
	Shortage of refrigerant.	Add refrigerant.
Low suction pressure	Restricted liquid line, expansion valve screen, or suction screens.	Pump down, remove, examine and clean screens.
	Insufficient gas in system.	Check for gas shortage.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.
	Improper adjustment of expansion valves.	Adjust valve to give more flow.
	Stuck or frozen expansion valve.	Tap or thaw expansion valve as necessary.
High suction pressure	Over feeding of expansion valve.	Regulate expansion valve, check thermal bulb attachment.
	Leaky suction or discharge valves.	Test with gages; if leaking, replace.
Compressor short cycles on (high pressure cutout)	Insufficient air flowing through condenser.	Remove any debris that would block the air flow.
	High pressure cutout incorrectly set.	Check setting of high pressure cutout.

Symptom or difficulty	Condition may be due to	Correction
	System overcharged with refrigerant. High Pressure cutout tripping due to insufficient condenser capacity.	Draw off refrigerant into service drum.
	Air or noncondensable gases in system.	Purge air from condenser.
Compressor short cycles on (low pressure cut-out)	Coils in refrigerators clogged with frost. Suction or expansion valve screens clogged.	Pump down and clean screens.
	Thermal bulb on expansion valve has lost charge.	Detach thermal bulb from suction line and hold in palm of hand, gripping the suction line with the other hand. If flooding through is observed, bulb has not lost its charge. If no flooding through is observed, replace expansion valve.
	(See low suction pressure above.)	(See low suction pressure, above.)
Compressor runs continuously	Shortage of refrigerant.	Test for leaks. Add refrigerant.
	Suction or discharge valves leak badly.	Test valves. If necessary, repair or replace.
	Head gasket blown between cylinders.	Replace gasket.
	Liquid, suction or expansion valve screen clogged. (With temperature control.)	Pump down and clean screens.
	Improper control settings, stuck electrical contacts.	Readjust control settings, clean and adjust contacts.

AIR COOLED CONDENSERS--Continued

Symptom or difficulty	Condition may be due to	Correction
Compressor noisy	Vibration; not bolted to foundation rigidly.	Bolt down rigidly.
	Too much oil in circulation causing hydraulic knock.	Check oil level.
	Slugging due to flooding back of refrigerant.	Open expansion valve wide; close. Check to see if thermal bulb is incorrectly placed or loose.
	Wear of parts such as piston pins, eccentrics, etc.	Determine location of cause. Repair or replace compressor.
	Excessive high head pressure.	Check high head pressure cause and correct.
	Lack of lubricating oil.	Check oil level and add as required.
Oil does not return to crankcase	Expansion valve not flooding coil.	Adjust to flood coil.
	Valve in oil return line closed or stuck shut.	Open.
Compressor will not start	Overload tripped, fuses blown.	Reset overload, replace fuses and examine for cause.
	Switch out.	Throw in switch.
	No charge of refrigerant in system operated by a low pressure control switch.	Recharge.
	Solenoid valve on liquid line closed.	Replace or repair.
	No voltage or low voltage.	Check for voltage.

Symptom or difficulty	Condition may be due to	Correction
Oil leaves crankcase	Too much refrigerant flooding back.	Readjust expansion valves. Check bulb attachment.
	Leaky piston rings or worn cylinders.	Replace rings or compressor, or rebore and refit.
	On starting, suction pressure drop too rapid.	Short cycle compressor on starting.
Cylinders and crankcase sweating	Too much oil in circulation. Liquid refrigerant returning to compressor.	Examine for conditions of refrigerant and correct the condition.
Crankcase frosting	Liquid refrigerant returning to compressor.	Adjust expansion valve.
Head gasket leaks	Head bolts stretched or washers crushed.	Examine gasket, replace if necessary. Tighten head bolts. Replace washers.

SAFETY PRECAUTIONS

The two chief sources of danger in a refrigeration system are defective electrical connections, and careless handling of refrigerants. In chapters 2 and 3 of this training course, you have been warned how necessary it is to study anew the training course, *Basic Electricity*, and have been advised never to attempt any electrical repairs beyond your knowledge and skill, but to ask for the services of an electrician.

In the matter of handling refrigerants, you will have to depend upon your own knowledge for your safety, and for the prevention of damage to equipment.

First, it is imperative that you know the markings of the gas cylinders with which you must work. Handle them carefully; keep them upright; never drop them nor

let them bump into obstructions; never store full cylinders in the sun, nor in a damp place; store all empties separately.

When refrigerant must be drawn out of a system into a cylinder, remember that 85 percent full is the maximum safe capacity of a gas cylinder.

In charging a system, keep a close watch upon gages, to avoid overcharging.

Never open a refrigerant line until all liquid refrigerant has been removed; line pressure should be down to from 1-1/2 to 5 lb.

Never allow any part of a refrigeration system to become overheated.

Never use a torch around a system that operates with an explosive refrigerant.

When you loosen a connection in which Freon 12 is confined, wear goggles to protect your eyes. If Freon 12 does come in contact with your eyes, use sterile mineral oil or olive oil as a soothing application. DO NOT RUB YOUR EYES. If possible, report at once to the medical officer.

If Freon 12 comes in contact with your skin, treat it as you would a frostbite.

Any person who is overcome in a space that lacks the necessary oxygen because of a high concentration of Freon 12 must be moved to a fresh air space, and then given artificial respiration.

SUPERVISORY RESPONSIBILITIES

At advanced bases, and on major movements, the Chief Utilities Man, or even a Utilities Man First Class, will have complete responsibility for operating, maintaining, and repairing refrigeration equipment. It is extremely important, therefore, that you master all the information given in this chapter in regard to basic principles of a refrigeration system, component parts of a refrigeration unit, and the procedures to follow in servicing these various parts. Until you thoroughly understand the operating principles and the service procedures involved, you are in no position to instruct and supervise lower-rated men.

If any portions of this chapter should be selected for special emphasis, they would be the sections that deal, respectively, with compressors, condensers, expansion valves, motor controls, and trouble shooting.

QUIZ

1. When the application of heat brings about a change of state in a body or substance, the heat is known as
   - (a) heat of condensation
   - (b) heat of fusion
   - (c) latent heat
   - (d) superheat
2. What is meant by sensible heat?
3. The British thermal unit (Btu) represents the quantity of heat required to raise the temperature of
   - (a) an ordinary mercury thermometer 1 degree
   - (b) a cubic centimeter of alcohol 1 degree centigrade
   - (c) a cubic centimeter of water 1 degree centigrade
   - (d) a pound of water 1 degree Fahrenheit
4. What is the pressure temperature relationship which forms the basis of mechanical refrigeration?
5. Name the 3 processes by which heat transfer takes place from a body of higher temperature to one of lower temperatures.
6. The type of mechanical refrigeration in which the refrigerant passes through a closed circuit, absorbing heat in one part of the system and releasing it in another is known as
   - (a) an absorption system
   - (b) a compression system
   - (c) a primary system
   - (d) a secondary system
7. Which type of refrigeration system employs heat energy to bring about the changes that produce a refrigeration cycle?
8. Name the 4 processes that make up the refrigeration cycle in a vapor compression system.
9. In a compression system, how is the condition of temperature difference necessary for heat transfer provided?

10. Upon which side of a compression system, high pressure or low pressure, does the refrigerant vaporize?

11. In a compression system, the unit which acts as a pump on the suction line is the
    (a) compressor
    (b) evaporator
    (c) refrigerant receiver
    (d) pressure control valve

12. Of the 3 types of compressors in common use, the one that is most likely to be used in large-scale refrigeration units is the
    (a) centrifugal
    (b) reciprocating
    (c) rotary
    (d) vane

13. In large refrigeration plants, a relief valve is sometimes installed across the compressor (between suction and discharge) to protect it from being damaged under what conditions?

14. In late-model domestic-type refrigeration units, the condenser is cooled in what manner?

15. Receivers to serve as storage tanks for refrigerant are not used in
    (a) dry systems
    (b) flooded systems
    (c) capillary tube systems
    (d) float control systems

16. When the refrigerant enters the expansion valve of a compression system, its pressure
    (a) has undergone a throttling process
    (b) immediately begins to expand
    (c) is the same as that at which it enters the evaporator
    (d) is the same as that at which it left the compressor

17. What is the function of an automatic expansion valve? Of a thermostatic expansion valve?

18. In which unit of a compression refrigeration system does the liquid refrigerant form vapor?

19. What is the advantage of using a volatile liquid of low boiling point as a primary refrigerant?

20. The boiling point of Freon 12 is
    (a) -11.36 F
    (b) -18 F
    (c) -21.7 F
    (d) -28 F

21. Why is ammonia, rather than Freon 12, used in large refrigeration plants?
22. Is methyl chloride considered poisonous? explosive?
23. In small, self-contained refrigeration units, how is the selector dial connected, in order to control cabinet temperature?
24. The optimum temperature for a storage space used for dairy products is about
    (a) 30 F
    (b) 36 F
    (c) 40 F
    (d) 46 F
25. The frozen food space requirement suggested for installations having fewer than 2,500 men is
    (a) 100 sq ft
    (b) 500 sq ft
    (c) 0.3 sq ft per man
    (d) 0.4 sq ft per man
26. Why are the evaporative condensers of cold storage plants located adjacent to outside walls?
27. Why is heating of cold storage plants necessary in cold climates?
28. What is the chief purpose of maintaining an operating log on refrigeration equipment maintenance and repair?
29. What is meant by the term "hermetic motors"?
30. What is the distinction between a temperature differential and a range adjustment?
31. Name 3 factors pertaining to heat load in a refrigeration cabinet that enter into calculation of the service load.
32. What is the effect of moisture freezing on the surface of the cooling coil?
33. Why is a deep vacuum drawn on all new refrigerator installations, before they are put into service?
34. Testing for small leaks in a system requires that the pressure inside the system be
    (a) completely eliminated
    (b) no higher than 1.5 psi
    (c) no higher than 22.5 psi
    (d) at least 40 to 50 psi
35. What device is used in testing for leaks in a system using ammonia as the refrigerant?
36. When a system must be charged with refrigerant, or when some refrigerant must be added, what is the first precaution you must take?
37. If multiple V-belts on one drive are not uniform in length and tension, what will be the result?

38. The refrigerant flow controlling device that must not be set until the refrigerator has gone several times through its normal operating cycle is the
    (a) thermostatic expansion valve
    (b) high float valve
    (c) low float valve
    (d) capillary tube
39. What are the 2 chief sources of danger to personnel operating a refrigeration system?
40. What is the maximum safe capacity of a gas cylinder?

CHAPTER 5

AIR CONDITIONING

THEORY OF AIR CONDITIONING

Human comfort is influenced to a great extent by the humidity, or amount of moisture present in the atmosphere. The common expression, "It isn't the heat; it's the humidity," is an indication of the popular recognition of the discomfort-producing effects of moisture-laden air in hot weather. Extremely low moisture content also has undesirable effects on the human body. The measurement and control of the moisture content of the air is an important phase of air conditioning engineering.

Saturated Air

The air holds varying amounts of water vapor, and as temperature rises, the amount of moisture that the air can hold increases. But for every temperature that the air is capable of holding, when air at a given temperature attains the maximum amount of moisture that it can hold, it is known as saturated air.

DEW POINT.—The saturation point is usually called the dew point. If the temperature of saturated air falls below its dew point, some of the water vapor in the air must condense to water. The dew that appears on foliage when temperature drops during the non-sunlight hours is such a condensation. The "sweating" of cold water pipes, which is the result of water from the air condensing on the cold surface of the pipes, is another example.

Absolute and Specific Humidity

The amount of water vapor in the air is expressed in terms of the weight of the moisture. This weight is usually given in grains (7,000 grains equal 1 pound). Absolute humidity is the weight of water vapor in grains per cubic foot of air. Specific humidity is the weight of water vapor in grains per pound of dry air. It should be understood that these definitions refer only to moisture in the vapor state, and not in any way to the moisture (such as fog, rain, or dew) that may be present in the liquid state.

Relative Humidity

Relative humidity is the ratio of the weight of water vapor in a sample of air to the weight of water vapor that the same sample of air could contain if saturated. This ratio is usually stated as a percentage.

For example, when air is fully saturated, its relative humidity is 100 per cent. When air contains no moisture at all, its relative humidity is zero per cent. If air is half saturated, its relative humidity is 50 per cent.

As far as comfort or discomfort resulting from humidity is concerned, it is the relative humidity and not the absolute or specific humidity that is the important factor. This can be easily appreciated from the discussion that follows.

Moisture always travels from regions of greater wetness to regions of lesser wetness, just as heat travels from regions of higher temperature to regions of lower temperature. If the air above a liquid is saturated, the two are in equilibrium and no moisture can travel from the liquid to the air; that is, the liquid CANNOT EVAPORATE. If the air is only partially saturated, some moisture can travel to the air; that is, some evaporation can take place.

Suppose the specific humidity of the air is 120 grains per pound of dry air. This is the actual weight of the water vapor in the air. If the temperature of the air is 76 F, the relative humidity is then nearly 90 percent; that is, the air is nearly saturated. Although the body may perspire freely, the perspiration does not evaporate rapidly--because the air already contains nearly all the moisture it can hold--and a general feeling of discomfort results.

However, if the temperature for the air were 86 F, the relative humidity would then be only 64 per cent. That is, although the absolute amount of moisture in the air is the same, the relative amount is less, because at 86 F the air is capable of holding more water vapor than it can hold at 76 F. The body is now able to evaporate its excess moisture, and the general feeling is much more agreeable, even though the temperature of the air is 10 degrees warmer. Control of relative humidity is of extreme importance in air conditioning.

Heat of the Air

The heat of air is considered from three standpoints, differentiated as sensible, latent, and total heat.

Sensible heat is that measured by the household, or dry-bulb, thermometers. This is the temperature of the air itself, without regard to any humidity it may contain. It may be best to emphasize this by stating that sensible heat is the heat of dry air.

Air nearly always contains more or less moisture. Conditions of complete absence of moisture are rare, occuring perhaps only in desert regions. Any water vapor present, of course, contains the latent heat, which is generally referred to as the latent heat in the air.

Any mixture of dry air and water vapor—that is, air as we usually find it—contains both sensible and latent heat. The sum of the sensible heat and the latent heat in a sample of air is called the total heat of the air. Zero degrees is usually taken as a convenient starting point from which to measure total heat.

Since air conditioning operations deal with the various heats of the air and the condensation of moisture, THREE DIFFERENT TEMPERATURES ARE INVOLVED: dry-bulb, wet-bulb, and dew-point temperatures.

Dry-bulb temperature is the temperature of the sensible heat of the air, as measured by an ordinary thermometer. Such a thermometer in air conditioning engineering is referred to as a dry-bulb thermometer because its bulb is dry, in contrast with the wet-bulb type next described.

Wet-bulb temperature is best explained by a description of the wet-bulb thermometer. This is an ordinary

thermometer, with a loosely woven cloth sleeve or wick placed around its bulb, and then wet with water. The fabric must be clean and free from oil, and it must be thoroughly wet with clean fresh water. The water in the sleeve or wick is caused to evaporate by a current of air at high velocity. This evaporation withdraws heat from the thermometer bulb, lowering the temperature a number of degrees. The difference between the dry-bulb and wet-bulb temperature is called the wet-bulb depression. The wet-bulb temperature is the same as the dry-bulb when the air is saturated (that is, when evaporation cannot take place). The condition of saturation, however, is unusual, and a wet-bulb depression is normally expected.

In air conditioning work, the wet-bulb and dry-bulb thermometer are usually mounted side by side on a frame to which a handle or short chain is attached so that the thermometers may be whirled in the air, thus providing a high-velocity air current that promotes evaporation. Such a device (fig. 5-1) is known as a sling psychrometer. The psychrometer must be whirled around rapidly, at least four times per second. When the wet-bulb thermometer is examined at intervals, its temperature reading will be found to be dropping; the reading below which no further drop is observed gives the correct wet-bulb temperature.

The dew point depends upon the amount of water vapor in the air. If air at a certain temperature is not saturated, and the temperature is lowered, a point is finally reached at which the air is saturated for lower temperature and condensation of the moisture then begins. This point is the dew-point temperature of the air for the quantity of water vapor present.

The definite RELATIONSHIPS BETWEEN THE THREE TEMPERATURES should be clearly understood. These relationships are:

1. When the air contains some moisture but is not saturated, the dew-point temperature is lower than the dry-bulb temperature, and the wet-bulb temperature lies between them.

2. As the amount of moisture in the air increases, the differences between the temperatures become less.

3. When the air is saturated, all these temperatures are the same.

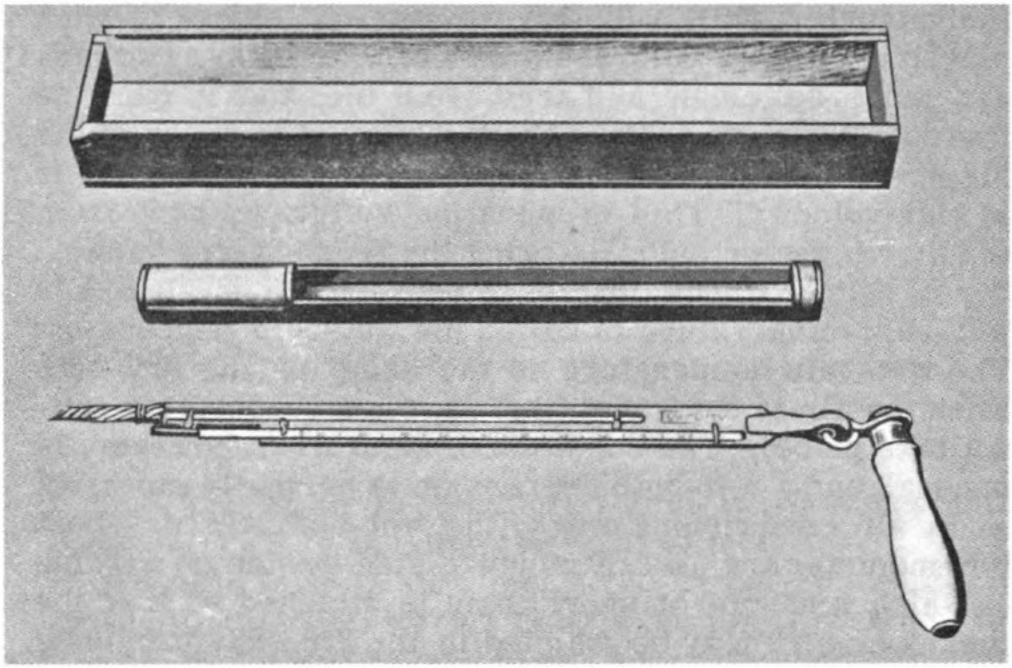


Figure 5-1.—Sling psychrometer.

Psychrometric Chart

There is a definite relationship between dry-bulb temperature, wet-bulb temperature, dew-point temperature, specific humidity, and relative humidity. Given any two, the others can be calculated. The relationship is illustrated on the psychrometric chart shown in figure 5-2. In air conditioning it is customary to use this chart, since reading measurements from the chart is far easier than calculating these measurements from two given factors.

Note that in this chart the wet-bulb and dew-point temperature scales lie along the same line, which is the 100 percent relative humidity line. The dew-point temperature lines, however, run horizontally, and the wet-bulb temperature lines run obliquely, to the right. To use the chart, take the point of intersection of the lines of the two known factors, and from this point follow the lines of the unknown factors to their numbered scales, and read the measurement.

Suppose the dry-bulb temperature were 70 F and the wet-bulb temperature 60 F, you would determine the dew-point temperature and the relative humidity in the following

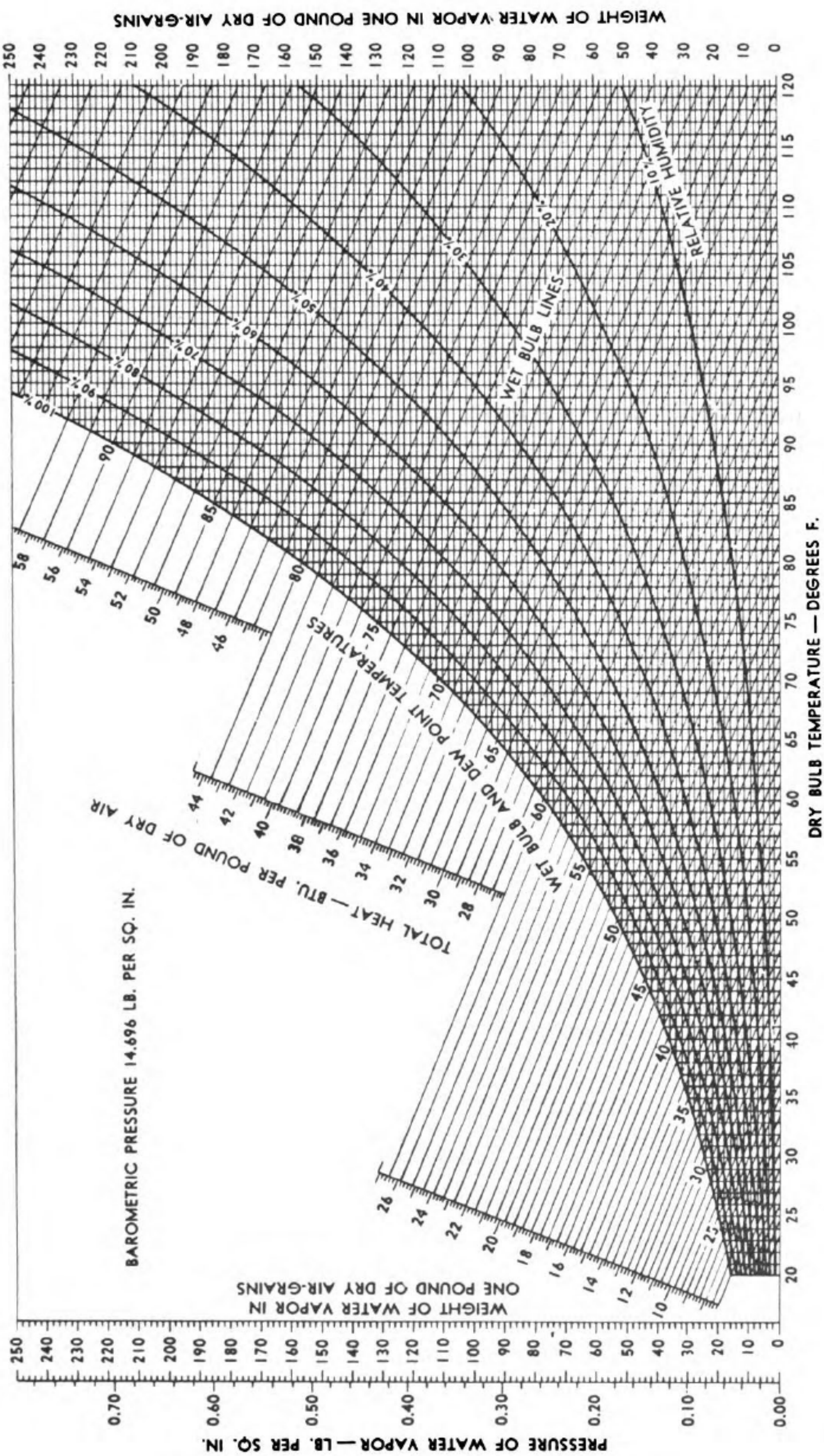


Figure 5-2.—Psychrometric chart.

manner. First, find the point of intersection between the dry- and wet-bulb temperature lines. From this point, follow along the dew-point line (horizontal) to the dew-point scale. The dew-point line temperature is 53.6 F. The relative humidity is 56 per cent (determined by interpolating the reading at the intersection point between curved relative humidity lines).

If the dew point were to remain at 53.6 F, and the air were to be raised to the dry-bulb temperature of 80 F, what would be the relative humidity? Follow the dew-point line to the 80 F dry-bulb temperature line; by interpolation, the relative humidity if 40.5 per cent.

If the dry-bulb temperature is 80 F, and the dew-point temperature 70 F, what will be the relative humidity when the dry-bulb temperature of the air is raised to 90 F? Note the point of intersection of the horizontal line running from the 70 F line with the vertical 80 F line. Follow this horizontal line to the 90 F dry-bulb line; at that point, the relative humidity reads 53 percent.

The actual weight of any amount of water vapor in air at any temperature can be read on the chart from the scale at the right-hand edge. Note the 70 F dry-bulb temperature line. From the intersection on the line of the various relative humidity percentage lines, follow the horizontal line to the right-hand scale, to read the number of grains of water vapor per pound of dry air. At the bottom is zero moisture of completely dry air. At the top is 100 percent saturation, such saturated air at 70 F holding a maximum of 110 grains per pound. The weight of water vapor that is contained in air at 70 F can be found, for any percentage of saturation, by starting with the given relative humidity point on the 70 F dry-bulb line, and following the horizontal line to the right-hand scale.

Air Motion

It is a well-known fact that when the air in a room is motionless, the room soon feels stuffy to its occupants, even though the air may be quite fresh. On the other hand, air that is somewhat stale does not feel stuffy if it is kept stirred; although it may, perhaps, be too warm, it is nevertheless bearable. Stirring of the air creates three effects, all adding up to a feeling of greater comfort. The

effects which air motion has (as a sensory effect, as a factor in humidity, and as a factor in temperature) are closely interrelated, and depend upon the velocity of the air.

The body is always evaporating moisture, even though the evaporation may be at such a slow rate that it is not perceptible as perspiration. If the air is still, this evaporated moisture stays close; it forms (with the heat also given off) a hot, damp, blanket around the body. Within such a blanket, air is less able to absorb the evaporation from the body; hence a feeling of discomfort ensues. But if the air is stirred, the convection currents thus formed carry away the moisture as rapidly as it is given off, and a normal rate of evaporation is maintained.

The human body is constantly giving off heat to the air around it, by conduction. If the air is still, the air close to the body gradually becomes heated, and this heat is not carried away by convection currents. Thus, although the average temperature of the air in a room may remain nearly constant, the body itself is in air of higher temperature. If the air is in motion, however, the heat coming from the body is carried away by convection before it can build up.

Body Heat Balance

Ordinarily the body remains at a fairly constant temperature of 98.6 F. It is very important that this body temperature be maintained; and since there is a continuous heat gain from surroundings, and from interior processes, there must also be a continuous outgo to maintain a balance. This excess heat must be absorbed by the surrounding air. The body adjusts to changes in local temperature and humidity by automatically regulating the amount of heat which it gives off.

However, this ability to adjust to varying environmental conditions is limited. Furthermore, although the body may adjust to certain atmospheric conditions, it may still experience a distinct feeling of discomfort.

BODY HEAT GAINS occur in several ways: (1) by radiation, (2) by convection, (3) by conduction, and (4) as a byproduct of physiological processes that take place within the body.

The heat radiation gain comes from our surroundings, but since heat always travels from regions of higher temperature to regions of lower temperature, the body receives heat only from those surroundings that have a temperature higher than 98.6 F. The greatest source of heat radiation is the sun. Indoor heat radiation is gained from heating devices, operating machinery, hot steam piping, and so forth.

The heat convection gain comes from currents of heated air only. Such currents of air may come from a galley stove or engine.

The heat conduction gain comes from objects with which the body, from time to time, is in contact.

Most of the body heat comes from within the body itself. Heat is being continuously produced inside the body by the oxidation of foodstuffs and other chemical processes, by friction and tension within the muscle tissues, and by other causes as yet not completely identified.

BODY HEAT LOSSES are of two types (1) loss of sensible heat, and (2) loss of latent heat. Sensible heat is given off by radiation, convection, or conduction. Latent heat is given off by evaporation.

The body is usually at a higher temperature than that of its surroundings, and therefore radiates heat to walls, floors, ceilings, and other objects. This type of body heat loss is called radiation loss. The temperature of the air does not influence this radiation, except as it may alter the temperature of such surroundings.

Body heat loss by convection occurs when the heat is carried away from the body by convection currents (both by the air coming out of the lungs and exterior air currents). Body heat loss by conduction is caused by bodily contact with cooler objects or substances.

The heat loss by evaporation is the loss of heat due to the cooling effect of vaporization of the body's moisture. Under normal air conditions, the body gets rid of excess heat by this method. The heat inside the body is sensible heat; in the evaporation process, it becomes latent heat. The rate of evaporation, and hence of heat loss, depends upon temperature and relative humidity, and upon the motion of the air.

When the temperature and the relative humidity are not too high, and when the body is not too active, the body

gets rid of its excess heat by radiation, convection, and conduction. When engaged in work or exercise, the body develops increased internal heat, and perspiration begins. Perspiration rapidly evaporates if the relative humidity is low. If, however, the relative humidity of the air is high, the moisture cannot evaporate, or does so only at a slow rate. In such cases, the excess heat cannot be removed by evaporation, and discomfort follows.

The amount of heat given off by the body varies according to the body's activity. When seated at rest, the average adult male gives off about 380 Btu per hour.

Research has shown that the total amount of heat loss for a person engaged in light work is divided as follows: about 45 percent by radiation, 30 percent by convection and conduction, and 25 percent by evaporation. For normal body comfort, it is important that heat loss be in these proportions.

If a person loses the same total of heat in the proportions of 40 percent by radiation, 50 percent by convection and conduction, and 10 percent by evaporation, he feels uncomfortable, damp, and chilly. This represents a condition of high relative humidity and too much air motion (a breeze from a fan or a direct draft). On the other hand, if the total heat loss is the same, but divided in the proportion of 30 percent by radiation, 25 percent by convection and conduction, and 45 percent by evaporation, a person will feel uncomfortable, hot, and parched. This represents a condition of low relative humidity and no air motion.

It is apparent that while the total heat loss may be a desirable amount, it may be given off so as to produce distinct discomfort. It is essential that the air conditioning be so controlled as to enable these heat losses to occur in the best proportions.

Sensation of Comfort

From the foregoing discussion it is evident that the three factors—temperature, humidity, and air motion—are closely interrelated in their effects upon comfort and health. In fact, a given combination of temperature, humidity, and air motion will produce the same feeling of warmth or coolness as a higher or lower temperature in

conjunction with a compensating humidity, and air motion. It is the net effect of these factors, then, in which we are interested. The name given to this net effect is EFFECTIVE TEMPERATURE (E.T.). This temperature cannot be measured by any instrument, but may be found on the psychrometric chart when the dry-bulb and wet-bulb temperature and air velocity are known.

Though all the combinations of temperature, relative humidity, and air motion of a particular effective temperature may produce the same feeling of warmth or coolness, they are not all equally comfortable. It has been found that a relative humidity below 45 percent produces a parched condition of the mucous membrane of the mouth, nose, and lungs, and increases susceptibility to disease germs. A relative humidity above 70 percent causes an accumulation of moisture in clothing. For best health conditions, relative humidity of from 40 to 50 percent for cold weather, and from 50 to 60 percent for warm weather, is desirable. An overall range, from 30 to 70 percent is acceptable.

There is also an optimum range of air velocity. This range varies from approximately 15 to 20 fpm to about 100 fpm. In general, if an air current is definitely perceptible—that is, if it attracts attention—then it is too much for comfort, and may be a hazard to health.

A comfort chart, constructed to indicate the ranges of temperatures, relative humidities, and air velocities which produce a normal feeling of comfort for most persons, is shown in figure 5-3. This chart is for air velocities of from 15 to 25 fpm. You will note that the range of acceptable conditions for winter is different from the range for summer.

Heat Loads

The air in any space to be mechanically cooled bears a heat load derived from several sources: personnel, equipment, air replenishment, and heat transfer from surrounding spaces.

The total heat load from personnel in the space remains practically constant regardless of ambient temperature, but the ratio of latent to sensible heat varies with temperature changes. When temperature within the space is

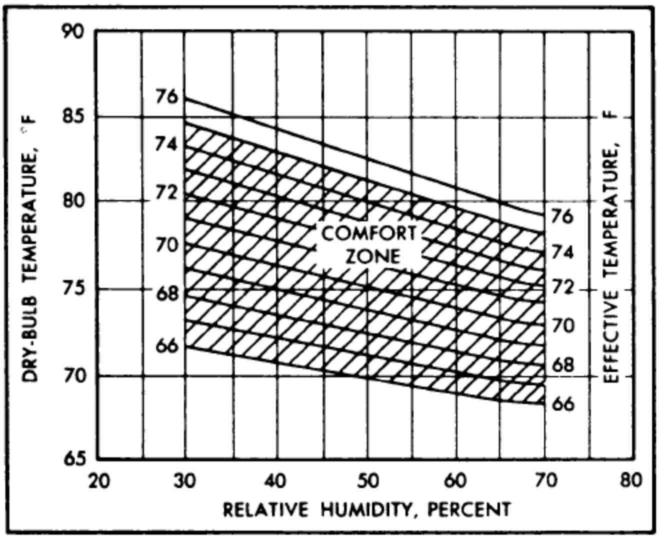


Figure 5-3.—Comfort zone, applicable dry bulb temperature and relative humidities.

very high, there will be a low addition of sensible heat from personnel, and a high addition of latent heat.

Electrical equipment contributes sensible heat to the heat load of the space. Within the operating range of temperature, this additional load will remain constant despite changes in space temperature. To keep this sensible heat load to a minimum, the use of any unnecessary electrical equipment, even light bulbs, should be avoided.

Replenishment air is necessary to some extent, even in a system that operates on the principle of recirculation. When this new air is admitted, it adds to the heat load.

The temperature of a cooled space is normally less than that of surrounding areas, and there will be some amount of heat transferred from these outside areas, to add to the net heat load of the space being cooled.

BASIC AIR CONDITIONING CYCLE

A space gains heat from the personnel and the equipment within the space, and from heat transmitted through the floor, walls, and ceiling. Moisture is added by personnel; and any sources of water that may be present in room or space will also give up moisture to the air.

Figure 5-4 illustrates the manner in which hot, moist air is drawn from a space to be air conditioned, is mixed with replenishment air, is cooled by being fan-driven

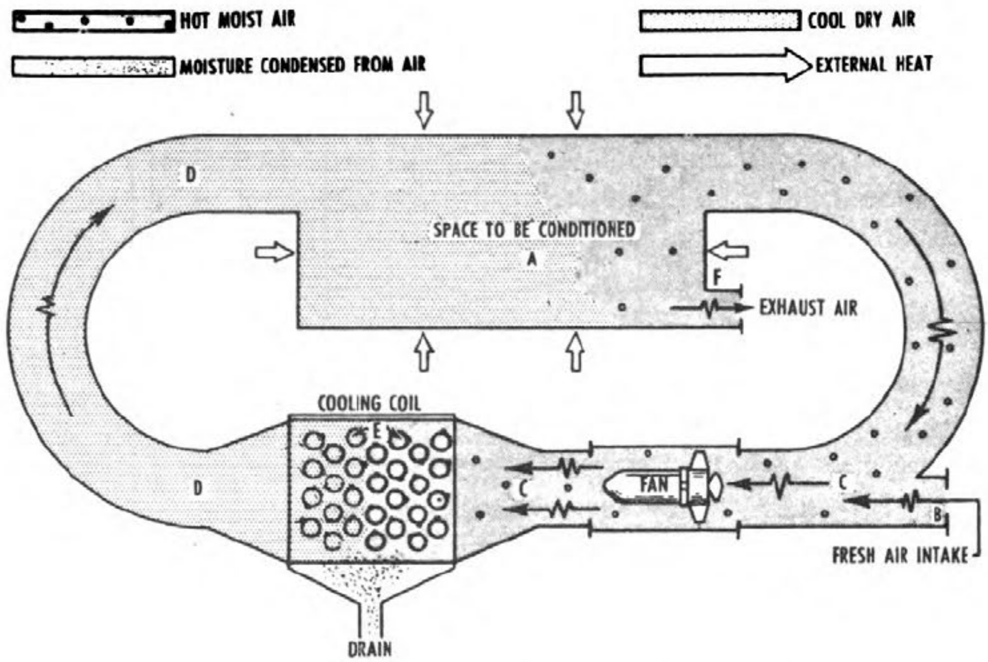


Figure 5-4.—Mechanical air cooling system.

across the refrigerant coils, and is returned again to the space.

Starting from the space to be cooled, the air conditioning cycle is as follows: hot, moist air from the space is drawn in from the outside. The fan blows the air over the cooling coil, and the refrigerant inside the coil cools the surface of the coils. These cold surfaces absorb the heat from the air passing over them and condense the excess moisture. The moisture drips off into a pan below the coils and is carried away by piping. The cool, dry air leaving the coil is blown into the compartment to be air conditioned, where it absorbs the excess heat and moisture in the space, and is then returned to the cooling coil. Air is exhausted from the space in order to allow for fresh air being drawn into the space.

Just as in a refrigerating system, the refrigerant in the evaporator coils absorbs heat from the air that is forced over the coils, and vaporizes. The vapor is then drawn into the compressor by suction, put under greater pressure by the pumping action of the compressor, and then delivered to the condenser.

Air from an outside source is drawn into the condenser, to pick up and discharge to the outside the heat

absorbed by the refrigerant in the evaporator coils. With the heat removed, the gas condenses to a liquid state again, and flows by gravity into the receiver.

The cycle is completed by the flow of the liquid refrigerant from the receiver to the evaporator. This flow is controlled and regulated by the expansion valve in the line ahead of the evaporator.

The evaporator, or cooling coils, may be located in or close to the spaces that are to be cooled. In large units, however, the refrigeration machinery may be at quite a distance from the cooled spaces.

Note that provision is made for exhausting some of the heated air. A compensating volume of air is then drawn in through the fresh air intake. The purpose of this replenishment is to prevent concentrations of CO_2, and to dissipate odors. Concentrations of CO (carbon monoxide) are unlikely to occur in any of the spaces in which the Utilities Man will operate.

In year-round air conditioning, some provision will be needed for ADDING heat, as well as removing it. Steam or hot water coils, incorporated into the cooling system, make it possible to use the same air-handling equipment in heating that is used in cooling. In determining heating requirements, the factors of heat transfer from surrounding spaces, and of air replenishment, are considered, as they are in computing cooling loads. However, the factors of heat gain from personnel and equipment are usually disregarded.

Heating units may be either coal or oil furnaces, gas burners, or electric heaters. The equipment used for heating usually is entirely automatic in its operation.

COAL FURNACE. The heat is formed by oxidation of carbon and hydrogen. (Oxidation means the combining with oxygen.) The coal furnace is the least efficient of the heating units enumerated above. Hand-fired furnaces are only 25 to 50 percent efficient; stoker-fired furnaces are 50 to 80 percent efficient.

OIL FURNACE. Oil under pressure is forced through the orifices, broken into fine particles (atomized), mixed with the proper proportion of air, and forced (by blower) into the combustion chamber. If a rotary burner is used, the rotary disk throws the oil against redhot plates of stainless steel. The oil, upon contact with these plates,

vaporizes completely. Combustion takes place at the point of vaporization.

GAS BURNER. Fuel is fed through the orifice, mixes with a specified amount of air, and is then fed to the burner orifice, where it mixes with secondary air. At this point, combustion occurs.

ELECTRIC HEATERS. These heaters, of course, produce heat through the medium of electrical resistances. In some systems, walls or glass panels, electrically heated, radiate heat. Split systems may heat one half of the air by radiant heat, and for the other half, employ "conditioned" circulated air.

TYPES OF PLANTS

The greater relative safety of air conditioning equipment that operates with hydrocarbon refrigerants is an important consideration in the selection of units. You will find that the refrigerant used in practically all air cooling coils is Freon 12, although in a few cases you may have to work with equipment which operates with chilled water, or with lithium bromide, as a secondary cooling medium.

The lithium bromide plant is one in which a cooled mineral-salt solution is circulated through the coils, to cool the circulated air. These plants are being less and less used by the Navy, but you may sometime have to operate one.

Chilled water circulating systems use water instead of Freon as the refrigerant. This system is becoming more common in use, since it provides for a relatively simple and low-cost operation. All the refrigeration machinery parts can be assembled in one space, and the refrigerant can then be circulated to remote spaces.

The water is chilled to a temperature between 45 and 50 F, in a water chiller located in the refrigeration machinery. This chilled water is then circulated through the coils in parallel, and back to the chiller for recooling. The distribution of cooling coils, fans, and ducts is the same as in other refrigerant-circulating systems.

SELF-CONTAINED AIR CONDITIONING UNITS

The small independent air conditioning units have far less flexibility, to meet load requirements, than do the large central systems. They are intended for use in spaces where exact temperature and humidity control is not critical. Compressor, condenser, evaporator, fan, filters, and controls are compactly assembled in a single installation. The smaller units are usually mounted in windows; the larger ones are floor-mounted.

SILL-MOUNTED units are from 1/2 to 2 hp capacity, and will effectively cool areas of from 150 to 400 sq ft floor space, and of conventional height. Because of their limited capacity, these units are not designed for automatic operation. Adjustable dampers allow for bringing fresh outside air into the conditioned space; on many units, these dampers can also be used to exhaust stale air.

Other window units, not sill-mounted, can be placed on the floor in front of the window, and at a distance of from 1 to 2 inches. Where radiators are installed beneath a window, it is oftentimes feasible to remove them to make space for the air conditioning unit. When colder weather comes, the radiators can be reinstalled.

An air conditioning unit mounted in front of a window should have ducts connecting with the outside, so that there will be the necessary provision for air intake and air discharge.

FLOOR-MOUNTED UNITS are of larger capacity than the window-mounted ones. Compressor, condenser, evaporator, with blowers, filters, and controls, are all housed within factory-assembled cabinets. Units of from 3 to 5 hp (see fig. 5-5) usually do not require air distribution duct work.

Air conditioning units used in hospital spaces are usually operated continuously throughout the year, without regard to seasonal changes in temperature. In this way, it is possible to maintain an even temperature, and the desired humidity conditions.

A system installed in a surgical operating room must supply 100 percent outside air to the space, to ensure that the vapors from ether and so forth will be diluted to the maximum extent. The exhausted air must be discharged

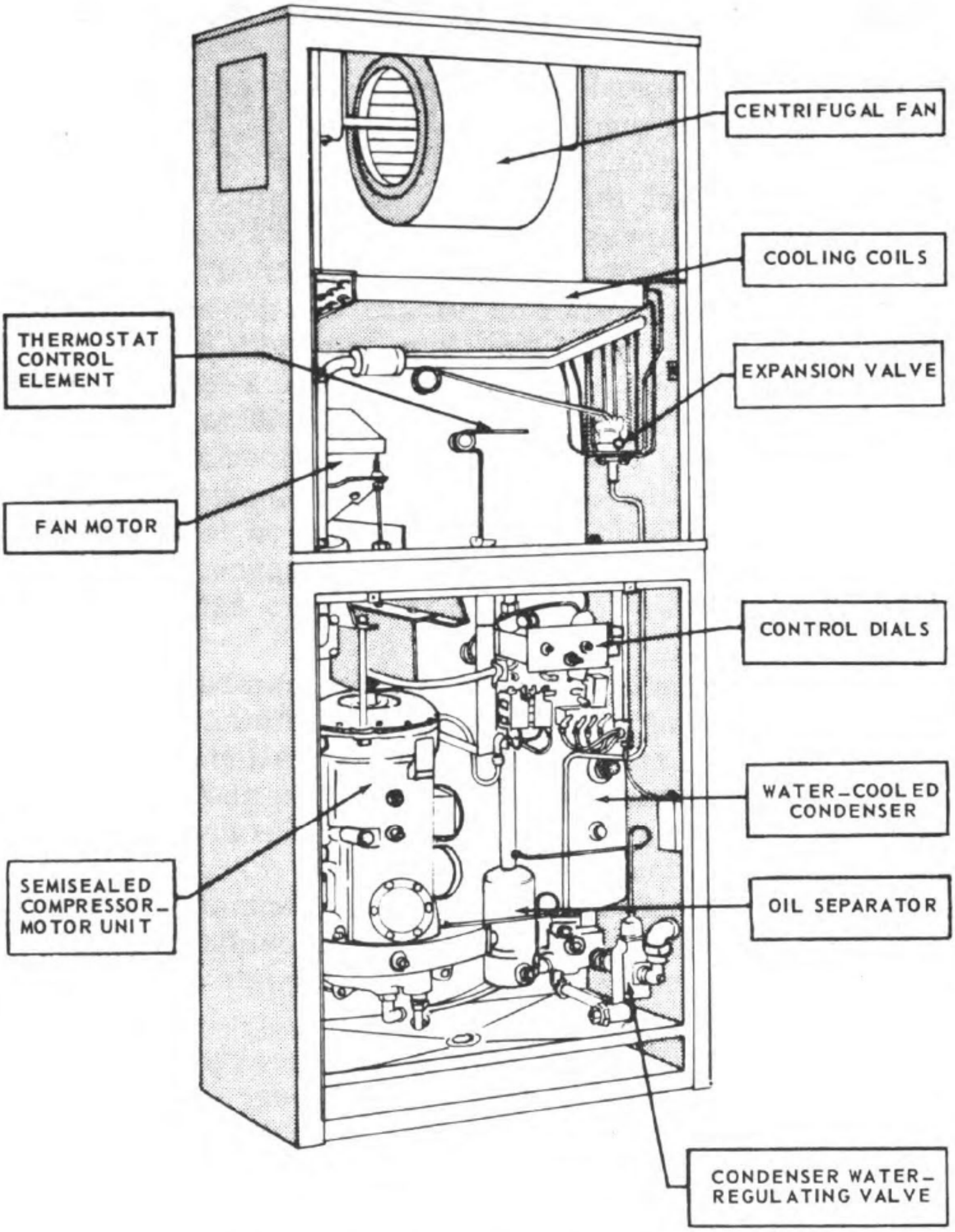


Figure 5-5.—Floor-mounted air conditioning unit.

to the outside, either directly, or through an adjacent sterilizing space.

Air supplied to an operating room must not be directed toward or over an operating table; it may cause a draft, or may carry an airborne infection, both of which could be harmful to a patient. The temperature should be adjusted to about 72 to 82 F, and the relative humidity should be

about 50 percent. The units must be provided with modern static grounding equipment, to eliminate as far as possible the danger of electrostatic spark explosions.

Spaces used for X-ray, dental, ear, eye, nose, and throat treatment, and spaces used as laboratories or dark rooms, or for the storing of chemicals, will require specific temperatures and humidities, depending upon the activities performed in those spaces. A mixture of 25 percent outside air and 75 percent recirculated air is satisfactory for most clinic spaces, and exhaust systems are not necessary. Fans must be installed in chemical storage rooms, dark rooms, and laboratories, however, to exhaust the fumes.

Temperatures in recovery rooms should be maintained at levels of 80 F or even higher, because patients are usually in a critical condition, and low temperatures would be very detrimental.

For some of these spaces assigned to specialized uses, requirements other than temperature and humidity may have to be considered. For example, the systems may have additional requirements, involving steam, hot water, or electric heating coils, humidifying devices, and extra filters.

Installation

In choosing the location for a unit, consider the following factors: weight and size of unit; length of necessary electrical connections; length of water and drainage connections; ducts required. Long runs of ductwork, or of utility connections, must be avoided when possible. Additional air filters must be installed in units that will serve hospital spaces. Exhaust fans must be provided for operating rooms and other spaces from which hazardous fumes must be withdrawn.

Set the unit on a firm foundation, to prevent excessive vibration, with consequent sagging or settling. See that water and drain lines have protection against freezing, and fit them with valves or unions, for easy draining. Ducts must be of fire-resistant material; if they are made of metal, connections to the unit should be of asbestos cloth, to prevent vibration. Where there are pronounced turns in ducts, turning vanes will be necessary. Slip joints must be in the direction of air flow.

Insulation

Supply air ducts that are carried through non conditioned spaces must be insulated to prevent undue warming of the air. Mineral wool, fiber glass, or rock cork, of about 1 in. thickness, can be used. A canvas or cement covering should be applied over the insulating material. For supply ducts in air-conditioned spaces, no insulation is required.

Ceiling insulation from 3 to 4 inches in thickness should be applied to air-conditioned rooms that are located just beneath flat roofs, or attic spaces. Flexible bat or a loose fill insulation may be used.

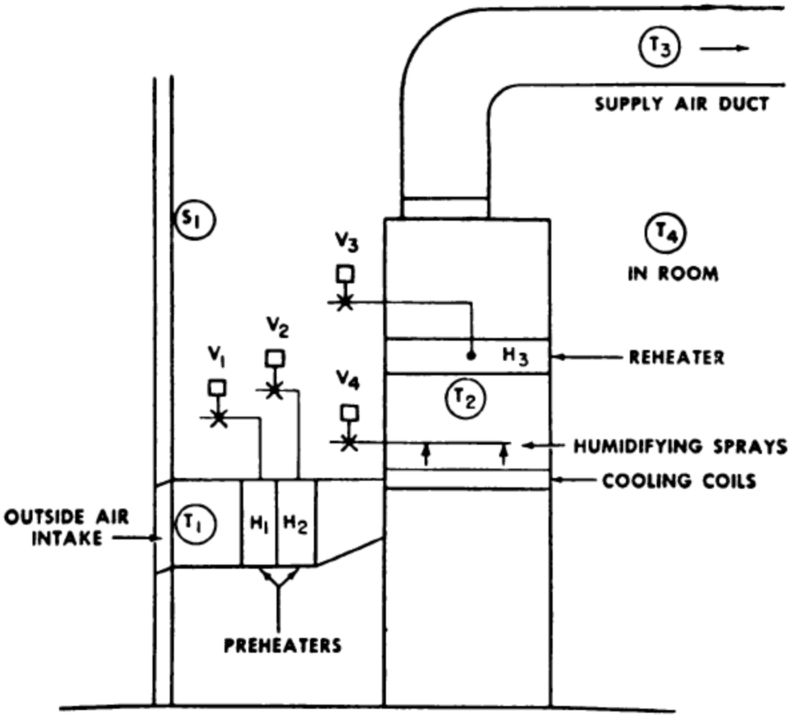
OPERATING CONTROLS.—A uniform distribution of air is made possible by grilles or registers, fitted with horizontal or vertical vanes. Adjustment of the vanes can be made to direct the air as desired. Control of the volume of air (outside air and return) is made possible by manual adjustment of dampers. Once proper adjustment has been made, the dampers can be locked to prevent any tampering with them.

Small units, either window- or floor-mounted, can be used as ventilating systems by operating the blower only. When this ventilating effect is not sufficient, the compressor can be set at the ON position; outside air intake dampers are set to allow minimum admission of outside air compatible with satisfactory room cooling effect.

Starting and stopping the compressor must be done manually on the window-mounted units, but in floor units, the compressor (once put in the ON position) starts and stops by action of a thermostat, according to variations in space temperature. In both types of units, the blower fan must be started and stopped manually.

Systems that are designed for summer-winter operation require additional equipment and controls. Such systems are needed for hospital spaces, especially operating rooms, where 100 percent fresh air intake is necessary, and where there should be a fairly constant temperature maintained during winter weather. The steam heating controls, temperature controls, and humidifying sprays that are needed are illustrated in figure 5-6.

When the switch is at summer position, the power circuits to T_1, T_2, T_3, V_1, V_2, V_3, and V_4 are deenergized.



NUMBERS SHOWN ARE FOR
MINNEAPOLIS HONEYWELL
INSTRUMENTS

T_1 = T615A 0°-70°
SET FOR 40°F
(OUTSIDE AIR 2-POSITION)
T_2 = T915A 0°-70°
SET FOR 60°F
(DEWPOINT MODULATING)
T_3 = T915A 60°-100°F
SET FOR 80°F
(DISCHARGE MODULATING)
H_1 = PREHEATER
—10° TO 36°F
H_2 = 30°F TO 120°F
H_3 = 60°F TO 90°F
V_1 = K-200B
(2-POSITION)
V_2 AND V_3 = K900B
(MODULATING)
T_4 = T615A 60°-100°F
(2-POSITION COOLING)
V_4 = WATER SOLENOID
S_1 = SUMMER-WINTER SWITCH

Figure 5-6.—Location of thermostats, heating units, and valves on a year-round air conditioning system.

The power circuit to T_4, in the room, is energized; this thermostat starts and stops the compressor motor, according to the prevailing temperature in the room.

Turning the summer-winter switch to winter position deenergizes T_4, and energizes T_1, T_2, and T_3. The water solenoid valve, V_4, opens, and V_1, V_2, and V_3 are also energized. When outside air goes below a temperature of 40 F, V_1, controlled by air thermostat T_1, opens. Thermostat T_3, in the supply air duct, controls valve V_3, to provide constant temperature in the air supply. Thermostat T_2 controls valve V_2, to ensure constant

temperature of the air leaving the humidifier spray section.

When one unit serves two or more operating rooms, each room has a temperature control thermostat, but only one room temperature controls at any time. A selector switch is used to place the selected room thermostat in control; the choice of rooms is made on the basis of importance of activities in the various rooms. Once the selection is made, the selector switch should be wired into position for as long as that particular thermostat is to be left in control.

Air conditioning systems installed for maintaining constant conditions of temperature and relative humidity should be started in sufficient time to produce these constant conditions before the room is put to use. Conversely, they should be stopped when it is anticipated that the room will not be in use for an extended period of time.

Central systems, as mentioned before, should be operated in accordance with the instructions supplied by the manufacturer. These instructions, or a carefully prepared set of rules embodying these instructions, should be mounted in a conspicuous place, close to the starting switches. Observance of these rules will ensure that motor starting and stopping, and adjustment of controls, are performed in such a way as to ensure proper functioning of the equipment.

In addition to temperature and humidity controls, an installation may have furnace controls, if it is designed to heat as well as cool the air. Then there are the refrigerant controls, similar to those used in a refrigeration system.

Furnace controls may be magnetic starters, solenoid valves, relays, or similar devices. Since the heating equipment must be automatic in its operation, these controls are all actuated by an electrical signal from a thermostat.

The refrigerant controls are thermostatic expansion valves, installed on the cooling coils. For maximum efficiency, it is advisable to install several expansion valves on one large coil. The self-contained units may employ capillary tube refrigerant control.

Most air conditioning installations have low pressure and high pressure controls, designed to lock the circulation

open if unusual pressure occurs. A circuit that has been deenergized by the action of these automatic controls cannot be closed again except by the operator manually turning on the unit. This necessity for manual cutting in ensures that the unit will be checked for any fault.

REPAIR AND OVERHAUL

The major maintenance problems will arise in connection with the self-contained units of 10 tons or less refrigeration capacity. Fans, filters, motors, dampers, and so forth are more vulnerable to dust and to foreign bodies than are the component parts of the large central systems. Faults arising in the control systems can also cause considerable trouble.

In advanced base installations, you are likely to encounter not only the usual difficulties connected with the air conditioning system as a piece of equipment, but also the difficulties arising from inadequate water and electrical services, and from lack of repair shop space.

The most important factors in maintenance of air conditioning equipment are cleanliness and competent operation. These two factors may be classed as preventive maintenance, and if sufficient attention is given to them, actual repairs can be held to a minimum.

Dust accumulations on the tubing or fins of compressors and condensers will prevent heat transfer; dirty air filters will prevent the adequate flow of supply air. Use brushes or vacuum cleaners to remove dirt. Clean or renew filters periodically. Replace disposable filters when a matting appears on their surfaces.

Before you change a filter, stop the blower. After changing or cleaning a filter, operate the fan, to remove any loose dust.

Refrigeration Systems

The refrigerating systems are maintained in the same way as other refrigerating systems (for preserving and freezing food products), but they operate at higher temperatures and suction pressures. Each unit should be cleaned at least once a year. Wire-brush all fan scrolls, fan wheels, coil casings, and drain pans, and check fan and motor bearings for any signs of excessive wear.

The refrigerants used in comfort air conditioning are Freon 12, and Freon 22. For safety reasons, the use of toxic or flammable refrigerant is not permitted. Ammonia and methyl chloride, therefore, must not be used.

In general, the safety precautions to observe with regard to the refrigerant in an air conditioning system are as follows:

1. Never mix different refrigerants in the same system. This rule applies to Freon 12 and Freon 22; a system designed for Freon 12 requires redesigning if Freon 22, or any other Freon-type refrigerant, is to be substituted.

2. Never fill a refrigeration system until the piping has been evacuated, cleaned, and dried free of moisture. Watch your moisture-indicating devices to see if the refrigerant has become contaminated with moisture.

3. Never operate the air conditioning system when the refrigerant supply in the system is very low. The first result would be that a layer of insulating frost would cover the evaporator, and no cooling would result. Then, because of nonstop operation of the unit, motor failure and damage to the compressor could occur.

Trouble Chart

The chart in figure 5-7 provides a guide to determining the cause of trouble in a system, when the cooling output is below unit capacity. Because most of your work will be with small self-contained units, you will find figure 5-8 a serviceable guide for general maintenance and overhaul.

Excessive Noise

Quiet operation of air conditioning units is a positive requirement in hospital spaces, and a highly desirable characteristic in living and working spaces. To test for excessive noise, turn the unit to full load operation. Then listen both outdoors and indoors for noisy operation of the equipment.

Locate these noise sources in respect to parts of the equipment, and try to analyze them. A frequent cause of operating noise, for example, is an unbalanced fan. Too

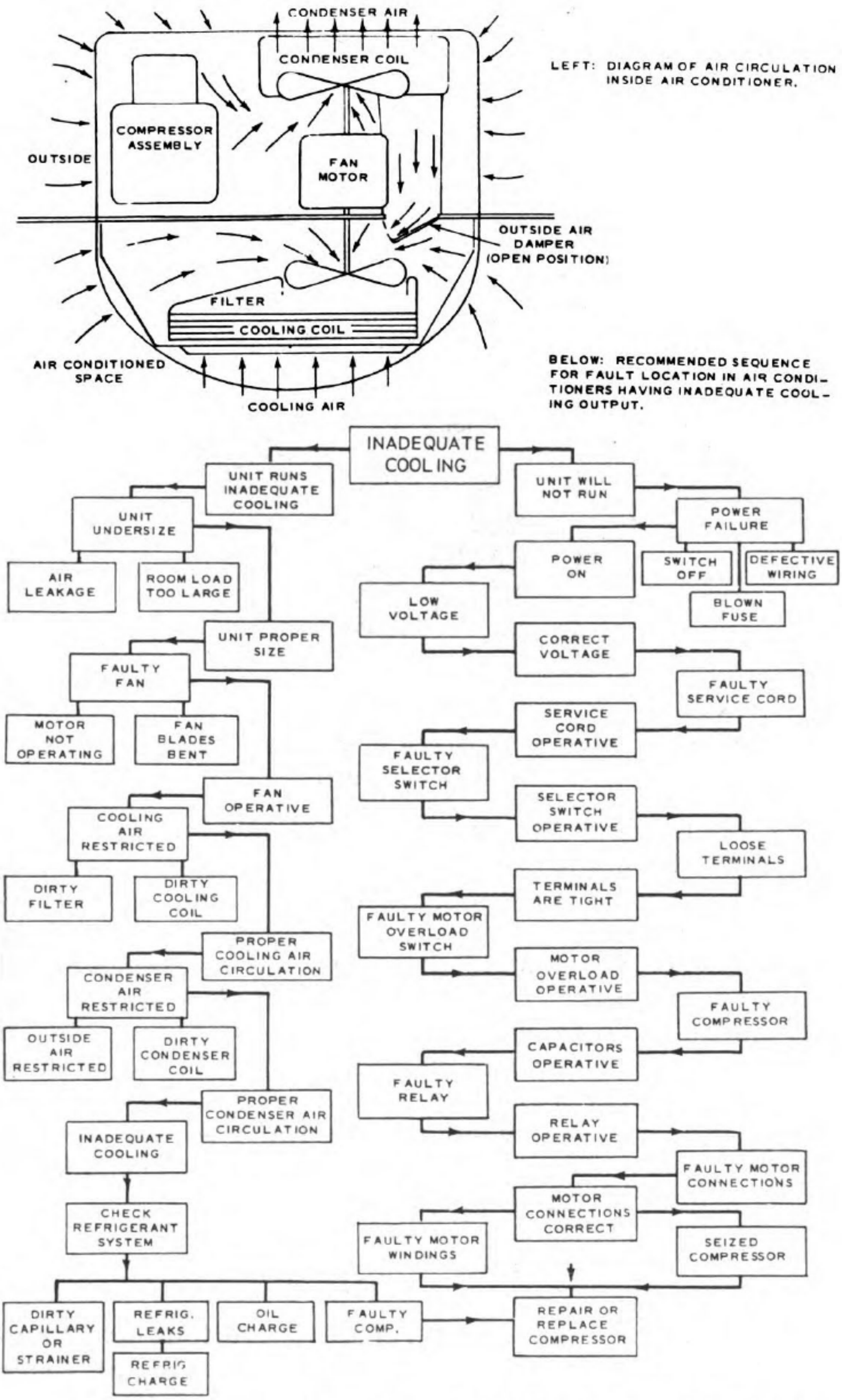


Figure 5-7.—Trouble-shooting chart for air conditioning systems.

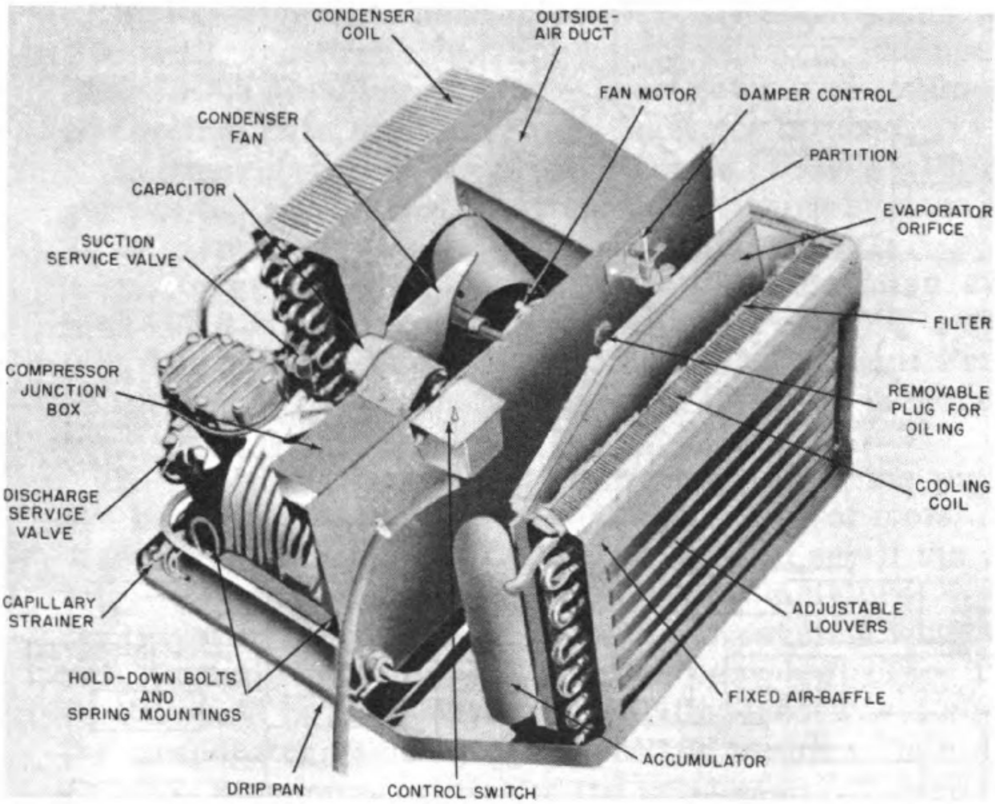


Figure 5-8.—Critical maintenance points in a window-mounted air conditioning unit.

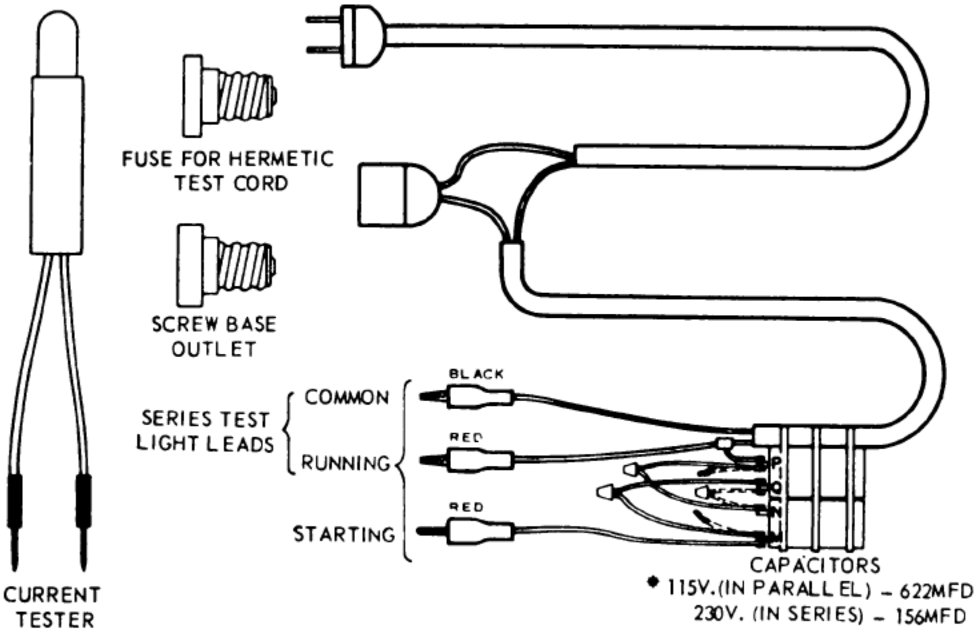
high a velocity of the air stream is another cause. Loose belts, faulty motor bearings, or misalignment of components can result in noisy operation of the unit. These defects, if neglected, may become a major repair problem.

In correcting defects, however, do not tamper with such components as hermetically sealed refrigeration equipment, or factory-calibrated automatic controls. In general, any components or devices that are covered by the manufacturer's guaranty should be replaced under the terms of that guaranty. If the warranty period has expired, it is advisable to have repairs accomplished by the manufacturer's service representative.

Repair Equipment

Small tools required for repair operations are hammers, hacksaws, tube and wire cutters, piping tools, wrenches, pliers, screw drivers, files, hand levels, and folding rules. You will also need such devices as the one

illustrated in figure 5-9, for testing electric current and voltage; a sling psychrometer; a halide torch; a gas torch outfit; pressure gages; and a refrigerant charging assembly.



* FOR 115 V. SERVICE, WIRE CAPACITORS IN PARALLEL BY CONNECTING CAPACITOR LEADS "M" TO "Q" AND "N" TO "P" WITH CONNECTORS. FOR 230 V. SERVICE, WIRE CAPACITORS IN SERIES BY CONNECTING CAPACITOR LEADS "N" TO "Q" WITH A CONNECTOR AND TAPE SEPARATELY ENDS OF LOOSE CAPACITOR LEADS "M" AND "P".

Figure 5-9.—Electric current tester.

In using the ampere and voltage testing device, you should wire your capacitors in parallel when testing on a 115-voltage service. Do this by connecting capacitor lead *M* to lead *Q*, and lead *N* to lead *P*. For a 230-volt line, wire the capacitors in series; connect the capacitor leads *N* and *Q*, and leave *M* and *P* loose, but tape their ends.

Repair equipment should also include basic supplies such as replaceable air filters, strainers, and tubing, wiring, and fittings. There should also be a reserve supply of the proper refrigerant, and silica gel or similar type of refrigerant moisture eliminator.

Repair spaces should be fitted with workbenches, platform scales, and bins for storing supplies. Outdoor racks in a shaded area will be required for storage of refrigerant tanks.

DEHUMIDIFYING THE AIR

Dehumidification is the process of reducing air humidity, so as to achieve the atmosphere required for personal comfort, or to retard the formation of mildew, mold, rust, or corrosion.

In the spaces occupied by personnel, excessive water vapor may come from a variety of sources: the breathing and perspiring of the people themselves, air that infiltrates into the space, or air entering as ventilation. These sources represent latent heat load, and the usual method of dehumidifying is to cool the air below its dewpoint, so that the unwanted water vapor will condense.

Another process of dehumidification is to bring the water vapor into contact with sorbent substances, which can extract and hold it. There are two general classes of sorbents; those which do not change physically or chemically when they extract the water vapor are called adsorbents, and those which undergo physical or chemical change (or both) are called absorbents. Silica gel is an adsorbent. Calcium chloride is a solid absorbent, and solutions of calcium chloride, lithium chloride, or lithium bromide are examples of liquid absorbents.

Control of humidity in storage spaces is very necessary, to prevent deterioration of materials. Once moisture has penetrated the structure and the supplies stored therein, the process of dehumidification may require a period of weeks or months. The proper procedure, therefore, is to prevent the relative humidity rising above a safe level. Usually an average of 40 percent relative humidity is considered satisfactory.

Roofs, sides, and floors of storage spaces should be watertight, and doors, windows, vents, and cracks sealed. The doors permitting access of personnel, and movement of freight, should be gasketed. Silica gel or some other type of adsorbent should be installed, to adsorb the moisture that will accumulate from stores turnover, and from air infiltration.

Sorbent dehumidifiers have definite limitations, and for climates in which the entering air does not drop below 60 F a standard refrigeration-type dehumidifier should be used. These units are available in fractional horsepower sizes, and are especially desirable in storage and

equipment spaces in humid climates, and where the removal of sensible heat by air conditioning is not a factor.

VENTILATION SYSTEMS

Natural ventilation takes place when the inside-outside temperature differences, and the natural forces of wind currents, induce air circulation and removal. The best arrangements for natural circulation of air are usually obtained when you have inlets at or near floor level, and escape outlets high on the walls, or in the roof.

Inlet openings should be placed so as to face directly into the prevailing wind; this provides for maximum air supply, but also makes screening of the vent a necessity. The air outlets should be placed at low pressure points, to prevent the used air being forced back into the ventilated spaces. The leeward side of a structure is a natural choice for these outlets.

If a continuous supply of outside air is necessary for comfort or for safe utilization of a space, some type of mechanical ventilation must be used. It is obvious that safe utilization of a space involves the exhausting of all hazardous fumes and explosive dust. Personnel comfort requires the exhausting of vitiated air, and the removal of objectionable odors.

The simplest type of mechanical ventilation may consist of ventilating fans only. However, a duct system must be provided in all cases where makeup air is a requirement—that is, wherever the amount of air exhausted exceeds the amount of air that can enter by normal infiltration.

Installations

The installation of attic-type propeller fans provides adequate ventilation for comfort in most cases. The suction created by the fans draws outside air through windows, doors, or other openings; the used air is discharged to the outside atmosphere.

Where hazardous vapors are drawn from individual spaces, it is necessary to install special sparkproof fans and motors, and to locate the air outlets in such a way as to prevent concentrations of the explosive or poisonous mixtures. The use to which the ventilated space is put

will influence the type of installation. The following information concerning requirements of specified individual spaces should be helpful.

1. Laundries and other work spaces that customarily have high temperatures should have vertical discharge propeller supply fans installed. Air flow in this type of installation is the opposite of air flow in the exhaust type system. Incoming air reaches the fan through a duct, and is then blown down and over the space at a velocity higher than that of the air in the exhaust system. This makes for greater comfort of the personnel working in these spaces. The used air is vented to the outside through windows and doors.

2. Kitchen ranges and deep-fat kettles are equipped with exhaust hoods. Air inlets must extend completely around the perimeter of the hood; exhaust air is discharged usually through the center of the hood area. The exhaust ducts, because of the high temperature of the outlet air, must be of metal, of cement, or of asbestos board; they must be at least 18 inches from any combustible material. Where the ductwork is extensive, use a centrifugal fan, of the overhung wheel type. Fan motors, bearings, and/or belts are thus outside the airstream. Fans and ductwork should be provided with a number of access openings, to facilitate cleaning.

3. Dishwashing spaces have to be ventilated to remove steam and vapors. Outside makeup air must be heated, because cold air will cause fogging when it mixes with the warm, vapor-laden air of the dishwashing space. Propeller fans with automatic louvers can be installed in the outside wall, adjacent to the dishwashing equipment. Excess discharge air can be exhausted near the ceiling of the space.

4. Bakeries require a filtered supply air; in an area where there are heavy concentrations of smoke or dust, makeup air should be supplied in excess of exhaust air, in order to keep the building under a slight positive pressure.

Spaces in which bread and other baked products are cooled and stored should have an exhaust air quantity that is slightly in excess of intake air quantity. Inlet air may be drawn from the interior spaces of the bakery; if an insufficient amount is available from such spaces, a

mechanical air supply system must be installed. All inlet air, whether from the bakery spaces or from the mechanical supply system, must be filtered. Cooling rooms should have airtight windows, airtight exterior doors, and reasonably airtight interior doors, to ensure that only filtered inlet air will be admitted.

The exhaust fan should be mounted so that it can be controlled from outside the cooling space, and it should be equipped with an indicating pilot light.

5. Garages, basements, and other spaces which cannot be ventilated by propeller type fan installations must have a system of ducts for supplying filtered air, cooled in summer and warmed in winter.

6. Paint shops that are used for year-round operations must be provided with a system of mechanical ventilation. All equipment must be explosionproof; and to prevent putting the space under positive pressure, the exhaust air quantity must be slightly in excess of the intake air quantity. Where paint-spraying is done, the air velocity over the work must be at least 125 fpm.

7. Toilets do not require mechanical ventilation if they have either a roof with an operable skylight, or an outside wall with one or more windows that can be opened at need. If a mechanical system must be installed, take care to prevent the discharge of air from the toilet into other building spaces.

In general, one or two large capacity fans will be much more effective than a number of small capacity fans distributed throughout the space to be ventilated. Where a single fan of adequate capacity is to be used, install it near the center of the space. Where it is necessary to depend upon a number of fans, of different capacities, position them according to capacity, rather than at regular intervals.

Safe installation demands that necessary strength be provided where ceiling or roof fans are mounted. Never cut through a structural member to install a fan. All fans that are mounted within reaching distance of the floor must be provided with guards.

Operation

Manual switches for all fans are located so that personnel working or living in the ventilated spaces may

operate the fans in accordance with requirements. Using personnel, however, should be instructed in the proper use.

Ventilation systems for the removal of dangerous fumes and vapors, for example, are not only operated during the processes which cause the fumes, but also for a sufficient period, after these work processes are finished, to rid the air completely of fumes.

Kitchen hood fans are operated while food is being cooked in the appliance served by the fan, and after cooking, also, if the food remains in the appliance.

Where fans are installed for personnel comfort, it is customary to operate them in the early evening and at night. In most cases, air in the building will be cooler than outside air in the morning hours. With the fans in operation, the windows in each room should be only partially open; this ensures a more equal distribution of the inlet air than would be obtained if all windows were opened wide. Width of window opening can be limited by installing stops in the window sashes. Large openings such as double doors should also be closed.

Maintenance

The important factors in the maintenance of a mechanical ventilation system are the same three factors that should be observed in the use of all mechanical equipment: cleanliness, lubrication, and periodic inspection.

Cleaning is best done by use of a vacuum cleaner. If cleaning has been neglected to a point where dust accumulations cannot be vacuumed away, it may be necessary to use a cleaning solvent. Use of a solvent, however, involves taking special precautions against vapor contamination and fire. Accumulations on range hoods can be broken up with a steam jet; have the flow downward, if possible, and provide a container for drains.

Upkeep maintenance and overhaul on motors should be done in accordance with the instructions contained in the manufacturers' manuals. Maintenance of fans, fan wheels, drive belts, and ductwork may be accomplished as described in the following paragraphs.

FANS should be completely disassembled, and checked for defects, at least once a year. The bearings of the motor and of the fan shaft should be cleaned, or if necessary replaced. Lubricate sleeve bearings with oil or grease. Ball bearings can be repacked with a soda-soap grease; high temperature ball bearings, however, should be oiled.

Lubrication depends upon service conditions, so no stated time periods can be specified. In lubricating, first remove all traces of the old lubrication, flush the bearings with kerosene, and then add the new lubrication.

FAN WHEELS (rotors) should be inspected periodically for wear. If a scraping noise develops, check the clearance between fan wheel and housing inlet. Handle fan wheels very carefully, so as not to destroy their balance, or otherwise damage them. Return wheels to the factory for reblading or other necessary repairs. If a wheel is allowed to wear out completely, it may collapse and damage the housing, the shaft, the bearings, or even the motor.

Repainting the frame, fan wheel, scroll casings, and ductwork will help to prevent corrosion, and will lengthen the life of the fan.

BELTS must be at right angles to motor shafts. For best results, the belts should be stretched slightly, but excessive tension will cause undue bearing pressure. On V-belts, it may be necessary from time to time to readjust the tension as the belt stretches under use. In changing belts, first slacken the tension; never prize or force a new belt into position.

DUCTWORK must be periodically inspected for deposits of lint, dirt, or grease. These deposits will increase air resistance, and thus cut down fan capacity; they are also fire hazards. It will often be necessary to install screens in the ducts for intake air, to keep out refuse and foreign material, and these screens also must be kept clean.

Exhaust ducts from kitchen ranges, or exhaust ducts in any system where the discharge air is grease laden, should be inspected once a month. In other duct systems that are operating normally, and where filters are cleaned or replaced regularly, a thorough inspection need not be made oftener than once a year.

SUPERVISORY RESPONSIBILITIES

As a Utilities Man First Class, or a Chief Utilities Man, it will be your responsibility to see that using personnel know how to get the best results from fans and other mechanical ventilation equipment. They should know when to use the system, how to adjust windows for optimum air intake, and when to ensure that 100 percent makeup air is available.

You will be expected to instruct them in the necessary maintenance procedures, especially those of keeping fan blades clean, and replacing or cleaning filters. Do not allow them, however, to adjust the automatic controls for heating and damper operation.

Because practically all ventilating and air conditioning equipment that you operate will be supplied by commercial companies, you should maintain a file of the material issued by the companies for operating and maintaining their equipment.

QUIZ

1. What is meant by the term "saturated air"?
2. The weight of water vapor in grains per lb of dry air is known as
   (a) absolute humidity
   (b) relative humidity
   (c) equilibrium humidity
   (d) specific humidity
3. Any mixture of dry air and water vapor contains
   (a) both sensible and latent heat
   (b) sensible heat only
   (c) latent heat only
   (d) both latent and specific heat
4. Under what condition is wet-bulb, dry-bulb, and dew-point temperature identical for a parcel of air?
5. In what 4 ways do human body heat gains occur?
6. Latent heat of the human body is given off by
   (a) conduction
   (b) convection
   (c) evaporation
   (d) radiation

7. For best health conditions in cold weather, relative humidity of the air should be within a range of
   (a) 30 to 40 percent
   (b) 40 to 50 percent
   (c) 50 to 60 percent
   (d) 60 to 70 percent
8. Where some provision must be made for adding heat, in a year-round air conditioning system, what two factors can usually be disregarded in computing heat load?
9. When a chilled water circulating system is used for air conditioning, the temperature of the water, when first circulated, should be
   (a) just above 32 F
   (b) between 35 and 40 F
   (c) between 40 and 45 F
   (d) between 45 and 50 F
10. What amount of floor space (assuming conventional height for the area) can a unit of 1/2 to 1 hp capacity be expected to cool?
11. In hospital air conditioning, a supply of 100 percent outside air must be provided for
    (a) spaces used for X-ray treatment
    (b) recovery rooms
    (c) surgical operating rooms
    (d) laboratory spaces
12. The horizontal or vertical vanes fitted to grilles serve to
    (a) control the volume of outside air and return air
    (b) control the distribution of air
    (c) prevent tampering with air volume controls
    (d) prevent the admission of an amount of air incompatible with fan capacity
13. What are the 4 major types of controls on a system designed to heat as well as cool the air?
14. Why is it particularly important to clean or renew air filters weekly?
15. May Freon 22 be used in a system designed for the use of Freon 12?
16. When you are testing a 115-voltage line with an ammeter and voltmeter testing device, should you wire the capacitors in series or in parallel?
17. To what use are sorbent substances put in air conditioning?

18. To prevent deterioration of materials because of humidity in storage spaces, it is usually satisfactory to maintain an average relative humidity of
    (a) 25 percent
    (b) 35 percent
    (c) 40 percent
    (d) 50 percent
19. To obtain the best possible circulation of air with natural ventilation, it is advisable that inlet openings be placed
    (a) facing directly into the prevailing wind
    (b) at points of relatively low pressure
    (c) high on the windward walls of the structure
    (d) low on the leeward walls of the structure
20. What are two elementary precautions that must be taken when fans are used to withdraw hazardous fumes from individual spaces?
21. Why is intake air flow given a downward direction and relatively high velocity, in laundries and other work spaces that have high temperatures?
22. Why must exhaust ducts from kitchen-range hoods be constructed of cement, asbestos or metal?
23. When a mechanical ventilation system is installed in a paint shop, why is provision made to have exhaust air quantity slightly in excess of intake air quantity?
    (a) To facilitate the removal of objectionable fumes
    (b) Because an added supply of air will infiltrate from surrounding spaces
    (c) Because this arrangement prevents the building up of pressure in the space
    (d) To increase the velocity of inlet air
24. Why are cleaning solvents not recommended for use in the maintenance of a mechanical ventilation system?
25. What is the purpose of painting not only the frame, but the rotor, casings, and ductwork of a fan?

CHAPTER 6

GALLEY EQUIPMENT

Maintenance of galley equipment, including heating units, and the machines, appliances, and fixtures for the bakery and scullery, must be performed in a way that will ensure safe, sanitary, and economical operation. The Utilities Man Second Class is supposed to be able to install and repair such equipment; and of course the Utilities Man First Class, and the Chief Utilities Man, should be able to instruct and supervise the lower-rated man.

Changes made in the Quals for Utilities Man, during the changeover from the rating pattern in effect until the end of 1957, were effected too late to allow for information on galley equipment being included in *Utilities Man 3 and 2*, NavPers 10656-C. For the time being, therefore, this material will form a part of the training manual for Utilities Man First Class and Chief Utilities Man.

Because of differences in each type of equipment, it is possible to give only general information; the manufacturers' instruction manuals that accompany new equipment should be kept as the best reference file for installation and repairs. However, you should be careful in installing electric equipment to see that it is put on the line (voltage and type of current) to which it is suited.

In regard to maintenance, the important thing is to keep all equipment in a condition that ensures safe, sanitary, and satisfactory operation. Safety of operation includes the necessity of giving due attention to electrical connections, insulation, and controls.

Keep in mind that the first lesson in maintaining the equipment is the importance of cleanliness about all parts of the machines and appliances. More failures of equipment are caused by dirt than by any other single factor.

SPACE HEATERS

Although not properly a part of galley equipment, space heaters should be mentioned here because the Utilities Man may be called upon to repair them. Stoves and space heaters have to be maintained at many installations to ensure the health of personnel and the efficient operation of equipment. A definite maintenance program should be developed, in accordance with the climate, and with the need for continuous or for seasonable operation. Equipment withdrawn from service, but to be put into use later, must be protected against corrosion and scale formation. The supply and return lines of steam and water unit heaters must be disconnected, and the heaters drained. Safety precautions require that the fuel lines of gas- and oil-fired units be secured OUTSIDE the building.

Inspection of electrical heating units and accessories should begin with a check for defective insulation, exposed conductors, and cracked porcelain. Observe also the operation of heating elements and controls.

At least once a year, give the equipment a general overhaul. Test the output temperature with a mercury thermometer. Repair or replace any defective wiring, elements, or controls.

Maintenance of gas and gasoline burners should include a thorough inspection of burners, controls, and piping. Look for dirt, soot, or other foreign matter which may be clogging openings. Clean all the parts, repairing and replacing any that would impair good operation of the burners.

The fuel must be fed properly to these burners, if they are to give satisfactory performance. Check the adjustment for fuel-air mixtures, the automatic controls, and the pilot. Examine the draft diverters, also, and clean out any soot in the openings.

Maintenance of steam heating units calls for the removal of external deposits of soot, dust, and corrosion from steam coils and finned-tube elements. This cleaning can be done with a brush and a vacuum cleaner.

In some cases, the construction of the unit heater may make it impossible to cover the motor, so as to protect it against dust when the unit is not in use. On this type of equipment, it will be best to close and seal the louvers with waterproof paper and tape.

Since a uniform distribution of heat is desired, test for cool spots by passing your hand across the element, and in a vertical direction. A cool spot indicates entrapped air or condensate; bleed or vent the element free of air or water. Check also for dirty strainers, defective valves, inoperative steam traps, and leaks.

RANGES

Most ranges are composite pieces of equipment, comprising a cooking top, oven, broiler, griddle, and frying kettle. They may be heated by electric elements, or by oil or gas burners. Whatever the heating device, it must be maintained in a safe and economical operating condition. General cleaning should both precede and follow use of a range.

Ranges must be free of dirt, grease incrustations, corrosion, or other conditions that would detract from good sanitation or good performance. Tops of ranges must be level, and burners should be frequently checked for any sign of loose connections, cracks, or plugged openings.

Figure 6-1 illustrates a typical range installation, composed of several units. Note the ventilation hood and grease filters.

Maintenance of these range units is best accomplished by having a schedule of monthly inspections, and a general overhaul of the equipment once a year.

In making the monthly inspections, test the level of the top of each unit, and make sure that proper alignment exists between all components. Check the fit of oven doors, and the sliding action of racks.

On electric ranges, use a voltmeter to check the voltage of the safety switch, and examine the fuses for

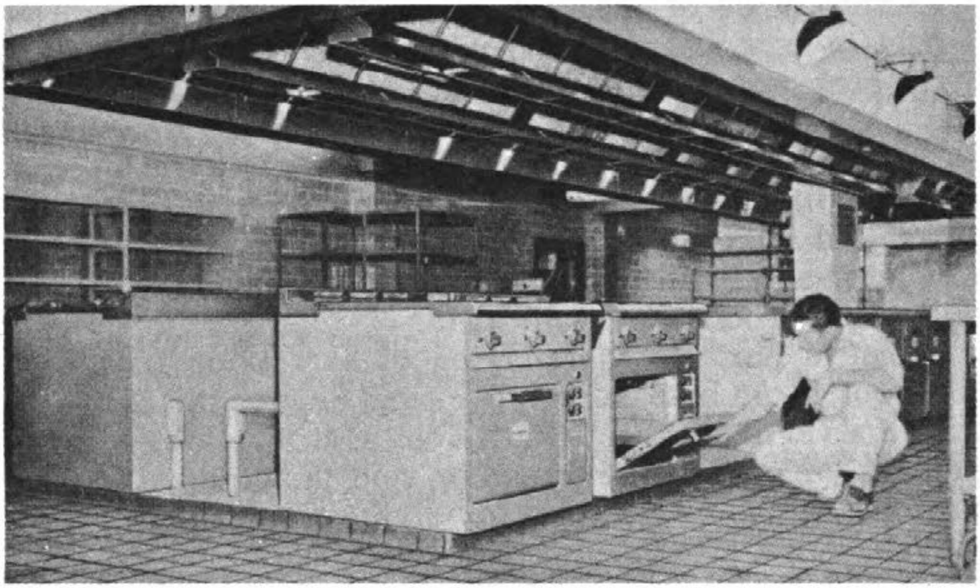


Figure 6-1.—Typical range installation.

correct amperage. Look for loose connections or worn insulation, check the heating elements and switches, and where any defective parts are found, clean, repair, and replace as necessary.

On the heating units for gas- and oil-fired ranges, a check should be made for soot deposits, clogging of the jet openings, and leaks in piping. Adjust the fuel-air mixture to produce a blue flame, and adjust the pilot if the flame is too high.

Annual overhaul must include a thorough inspection of all components, inside and out, for any sign of rust, corrosion, or other damage. Check for moisture-rust at the floorline; after the removal of rust or corrosion, patch-paint the bare spots with heat-resistant aluminum paint.

Inspect heating units, receptacles, wiring, and switches for breaks or loose contacts. Clean electric contacts with a fine sandpaper, but do not use an emery cloth. With a voltmeter, check the voltage at the switch. Check for any leaks in piping, using the soap-suds test on gas-fired units.

With a mercury thermometer, test the accuracy of oven thermostats and multistep heat controls, and make a record of the ON and OFF temperatures of the thermostats. Unreliable temperature controls can result in

considerable waste of food, so if you cannot adjust a thermostat to within 5 F of preset temperature, it will be economy in the long run to replace it with a new one.

Ovens

Electrically operated ovens are sectional; separate thermostats provide automatic temperature control, and there are individual rotary switches. Each section, therefore, can be separately operated. The assemblies may be composed of roasting ovens only, of baking ovens only, or of a combination of both.

Every two weeks, such oven assemblies should be disconnected from the power supply. A check should then be made for loose connections, or loose fuse clips. In case of any serious defect, a Construction Electrician should be called to make repairs.

Various types of baking ovens are used, according to the type of fuel available, and also to the product demand. There may even be some old-type brick ovens, hand fired, although these are used principally as portable field ovens. Their maintenance consists chiefly in shaking the grates occasionally to remove the ashes, and in keeping the grates free of clinkers.

In the case of electrically heated ovens, and those fired by gas or oil, temperature and humidity controls must operate within the preset limits, and counterweights and door latches must be performing satisfactorily, or else there will be a loss of heat, with consequent spoiling of the food being baked.

Broilers

Whether electrically heated or gas-fired, broilers may be part of a range unit or may be individual pieces of equipment. They must be kept in safe operating condition, and must be sanitary and free of corrosion. Maintenance procedures are the same as those already outlined for the ranges.

Griddles

Griddles may be part of a range unit, or separate equipment; they may be heated by gas or by electricity.

The best method of ensuring their safe, economical, and sanitary operation is a system of monthly and annual inspections.

Once each month, check the griddles and guards for evidence of corrosion. Check the connections, to make sure that all electric wiring has good insulation, and that there are no leaks around the gas cocks or the gas piping.

Gas burner orifices can soon become plugged with dirt, crumbs, soot, or rust, so that monthly cleaning is a necessity. At the same time, the flame should be checked, and any necessary adjustment of the fuel-air mixture should be made.

Test the heating elements in electrically operated griddles for uniformity of heat at low, medium, and high heat ranges. Carbon deposits, which can interfere with heat transfer, should be wiped off with a cloth dampened in a solution of household ammonia. Black pilot lights, burnt-out elements, and defective wiring, switches, or other controls must be replaced with new parts.

The annual overhaul should include a check of the griddle frame and casing to see if there is any corrosion, or if repainting is needed. Tighten loose bolts and nuts, scrape corroded areas with a wire brush, and repaint bare surfaces with heat-resistant aluminum paint.

Besides making this general check for cleanliness, and for parts that may be loose or broken, you should inspect gas cocks and electric switches for needed repairs. Replace cracked or badly chipped porcelain connections, and gas burners that have become badly corroded, or that have 30 percent of the orifices choked by insoluble deposits.

Frying Kettles

Fry-kettles built into a range unit must be level, and free of leaks or cracks; these are necessary precautions, since inadvertent escape of hot fat could cause fire, or injury to personnel. The individual deep-fat frying units, whether gas or electric, must also be maintained in a safe operating condition. Corrosion will interfere with the taste of food prepared in these units, so they must be drained and cleaned immediately after use. Greasing

them lightly with unsalted lard, or with a vegetable oil, will also prevent rust and corrosion.

The modern type of frying kettle is equipped with a sump, a drain pipe, and a gate valve, for draining off the fat. Thermostats, fuses, switches, and heating unit terminals are located in a compartment on the front of each kettle.

Proper maintenance requires that the baskets be examined monthly for breaks, and the deep-fat compartment and drain valve checked for possible leaks. If you are called to service this equipment, and find the steel surfaces corroded, you should notify the galley supervisor, because proper cleanliness is not being observed.

Remove all grease, dirt, carbon deposits; check the fuel-air mixture in gas-fired units, and the heating element in electric units. Repair or replace loose connections, cracked insulators, or defective controls.

Annual inspection should include a check to see if the unit is level. Rust or corrosion should be removed with a solvent, and the treated spots should be touched up with heat-resistant aluminum paint. Where a thermostat is installed, it should be checked, for both ON and OFF temperatures, with a mercury thermometer.

VEGETABLE STEAMERS

Some vegetable steamers are connected by piping to a steam distribution system, but others have built-in boilers fired with gas, oil, or coal. Figure 6-2 illustrates the type of unit that has pipe connections to a steam distribution system.

These steamers are constructed of cast iron or steel, with three or more compartments. The heavy doors are operated by handwheels, which do not show in the illustration, because the doors are opened. The doors are suspended on arms hinged to the body of the steamer; ball-bearing pressure screws on these arms close the doors, and gaskets of a special rubber composition maintain the seal.

Maintenance

The escape of steam or water from these cookers would be detrimental not only to the food being prepared,

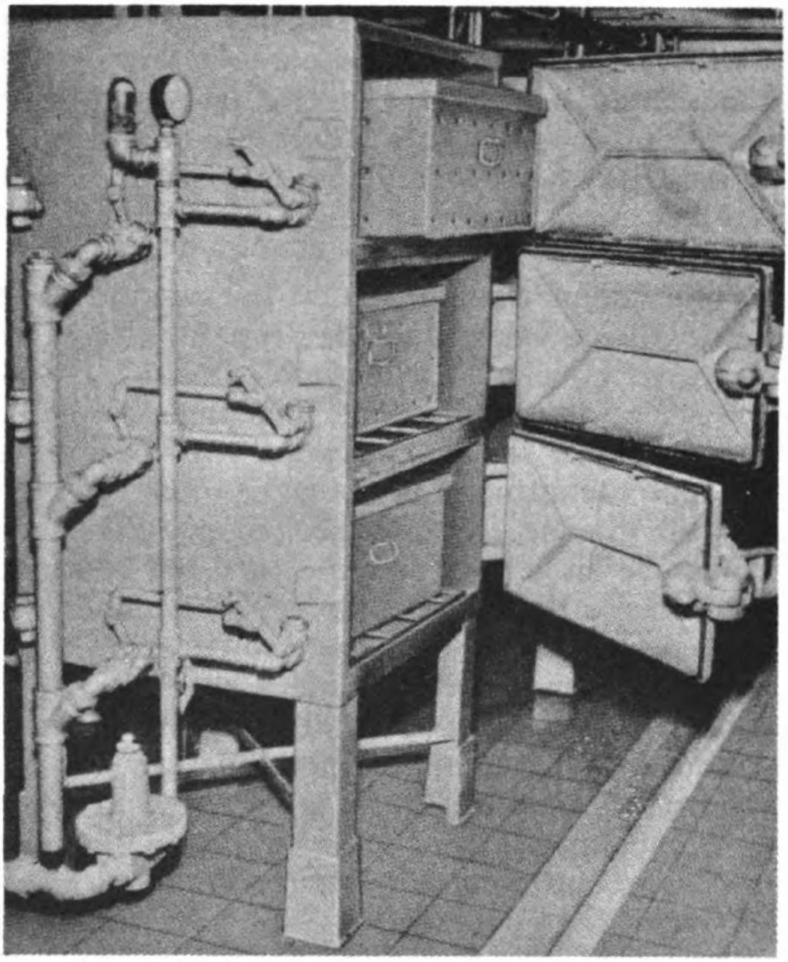


Figure 6-2.—Vegetable steamer, showing door latches linked to steam supply.

but also to the safety of personnel. Therefore, door latches, hinges, and gaskets must be maintained in close-fitting condition. The equipment must have a pressure-reducing valve to control inlet steam, and blow-off valve to permit the escape of steam that does not condense. A safety valve is also provided, in case of excess steam pressure.

Except for the necessity of ensuring steamtight operation, maintenance requirements on vegetable steamers are a minimum. Every week, a check should be made to make sure that the compartment drains are free of obstructions, that the door hinges, locking devices, and shelf drawbars are in good operating condition, and that the pressure setting of the gage on the low-pressure side is correct.

If a plunger-type valve is used with the locking device, the plunger must be adjusted so that the valve is fully depressed, when the door is closed; this allows the full complement of steam to enter the compartment. When the door is opened, the valve must function to completely stop the steam supply.

To ensure tight fit of the doors, replace hinge pins and bushings when they become excessively worn. Some full-floating doors are adjustable, by means of hexagon-head bolts extending through the door near each corner.

When gaskets must be replaced, remove the door from the unit. It will then be easier to remove the worn gasket, and to clean the channel. Be careful not to chip or damage the channel, since to do so would provide a path for steam leakage.

Apply gasket cement, and then force the new gasket into the channel at the corners, working it in toward the center of sides and ends. You are now ready to rehang the door; but first place paper along the edges of the door opening, to prevent excess cement from adhering to the mating surfaces when the door is closed. Any surplus cement can be cleaned off after it has hardened.

If the door has hexagon-head bolts, adjust them so that the closed door touches the steamer evenly, without binding at the corners. Unless you have a good fit, the gasket will be cut by the corners of the door.

Inspection

Monthly inspection should include the following: a careful inspection of steam piping, valves, and accessories for leaks; a check on steam pressure, with a test of the steam gage if there is any reason to believe it may be recording inaccurately; a check on the pressure-reducing and the safety valves; and a check to see if steam is being bypassed. The strainers between steam compartments, and the thermostatic traps, should be cleaned.

You will find that the usual source of difficulty with safety valves is internal clogging by rust, scale, or dirt, and the corrosion of springs, pins, levers, and discharge openings. If a safety valve is found to be in any way defective, the steamer must be taken out of service until the valve is either repaired or replaced.

The usual pressure setting for a safety valve is 8 psi, or 10 percent above working pressure. The pressure-reducing valve is usually set for 7 psi, although the maximum pressure as indicated on the steamer name-plate is allowable.

In checking the exterior of the machine for signs of corrosion, or need of paint, do not forget to also inspect the steam chambers, baskets, and pans, for corrosion or deformation.

As mentioned before, some cooker units have their own boiler unit, instead of a pipe linkage with a remote steam supply. Clean the burner openings, and check oil ignition devices, pilot flame, and draft diverter. Look for leaks in the gage glass, the automatic water-level valve, the water compartment, and all pipe connections. Make sure that all facilities for steam generation, fuel firing, water supply, and pressure regulation and control are in satisfactory operating condition.

At least once a year, these vegetable steamers should all be inspected, inside and out, for rust, corrosion, or bare spots that require paint. If more than 20 percent of the surface is bare, a complete repainting is justified.

During this general inspection, you should remove all safety valves, and thoroughly clean them. Apply a petroleum jelly lubricant to all moving parts. Wash the steam traps and condensate piping with hot, soapy water, and rinse in very hot, clear water. Check the steam chambers and the doors for leaks, and repair or replace gaskets that no longer provide for a steamtight condition.

STEAM-JACKET KETTLES

The usual type of steam-jacket kettle is the fixed-position kettle used for cooking. A tilting type of kettle serves for bakery use; and a plain kettle, equipped with heating unit and draw-off faucet, may serve as a substitute for a coffee urn.

Construction

Most steam-jacket kettles are made of aluminum or of corrosion-resistant steel. The jacket around the bottom-half allows for the circulation of steam between

the jacket and the kettle, to keep the contents hot. The hinged lid must fit properly to prevent the escape of heat from the food.

At the bottom of the unit is a tube with a draw-off faucet. Connections provide for steam inlet and steam outlet, and there is an exhaust outlet for vapor. A safety valve provides release when pressure in the jacket exceeds safe limits. Figure 6-3 illustrates a steam-jacket kettle assembly, with steam traps and safety valves.

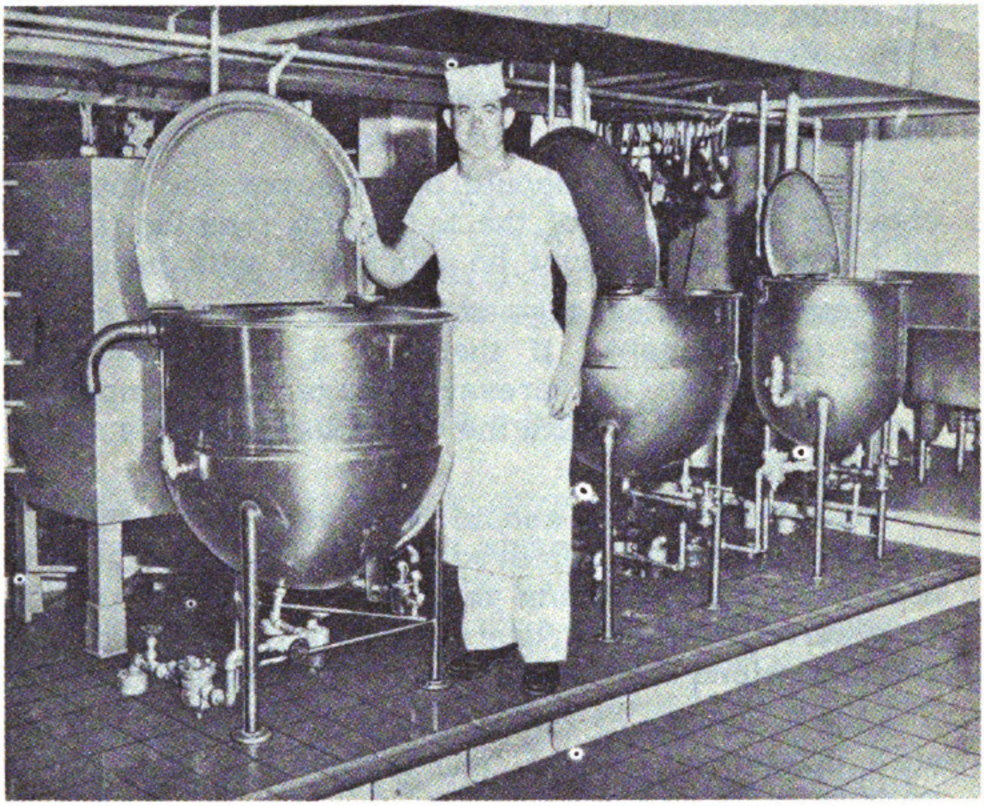


Figure 6-3.—Steam-jacket kettles, with steam traps and safety valves.

If a steam-jacket kettle fails to heat when the steam valve is open, there may be some defect in the supply line, or in the steam valve itself, or there may be an obstruction in the steam trap. If the kettle remains hot when the steam valve is closed, there must be a leakage of steam past the valve, and the valve probably needs refacing.

Inspection

Every month, you should make an inspection of the steam jacket, steam and water valves, draw-off faucets, and piping, to see if leaks have developed, or if any deposits are obstructing the flow of steam. Tapping the jacket walls with a wooden block, probing with steel wire, and blowing through with compressed air at a pressure up to 10 psi, should clean out scale and rust. Leaks can probably be repaired by tightening up packing and renewing valve seats.

The kettle itself should be inspected for corrosion (if made of zinc-coated steel), and for aluminum oxide film. Rust will require the use of solvents, but film can be removed simply by scouring and washing the kettle with hot, soapy water.

Strainer baskets should be removed and thoroughly cleaned; the hinges of the kettle lids (and the trunnions on tilting kettles) must be lubricated with mineral oil.

Clean the water gage and check the gage cocks for leaks or sediment. If there is a pressure-reducing valve, read the low-pressure gage and compare the recorded pressure with the operating pressure as given on the nameplate.

Annual inspection should be a very thorough one. If corrosion has to be removed, paint the bare surfaces with heat-resistant aluminum paint. Leaks in the kettle should be repaired by welding; dents should be filled with hot lead, and then wiped smooth with a paraffin-coated cloth pad.

Check the top of the kettle for levelness, and make sure that cover, hinges, and latches are a good fit, no warping or misalignment.

Look for possible leaks and obstructions in the steam and condensate piping, traps, valves, and accessories. Test the steam coil or the electric element for leaks or for breaks in insulation.

Remove safety valves for cleaning and lubrication, then test them and calibrate them. Check the calibration of steam gages by comparing them with test gages, and of thermostats by checking them with mercury thermometers.

STEAM TABLES

Steam tables, like all equipment with which food comes into contact, must be kept clean and corrosion free. Bare spots should be treated with vegetable oil; strainer baskets must be kept free of deposits that would clog the holes; and leaks should be stopped with welding or brazing.

These units may be heated by electric elements, or by gas burners or steam. Oil-fired units are not advisable, because of the danger that the fumes will contaminate the food. Whatever the heating device, it should be secured at the end of each day.

Monthly inspections involve checks on cleanliness, corrosion, leakage, wornout parts, insulation, gage pressure, fuel burner adjustment, and temperature controls.

Annual inspection should include a check of alignment, inspection of the water compartment and the table frame, examination of the heating elements and/or the fuel-air mixture, and a calibration of thermostats with a mercury thermometer.

MISCELLANEOUS EQUIPMENT

In many galleys, COFFEE URNS are set up in batteries; they are usually the steam-jacketed type, and are heated by electric elements, gas, or steam. In some cases, they will be individual urns with integral heating units, or plain kettles with heating units and draw-off faucets. Like all galley equipment, these urns must be kept in safe and sanitary operating condition.

Maintenance consists chiefly in checking heating units and thermostats for defects. On steam-heated units, the steam gage pressure must be kept within the maximum limit as indicated on the nameplate. Noticeable temperature differences between the upper and lower parts of a coil indicate that a defective steam trap or a clogged strainer is causing water or air to be trapped in the coil.

Once a year, the equipment should be disassembled, and the heating units, valves, faucets, pipe connections, liners, and gage glasses, inspected for possible defects.

Motor-operated MACHINES FOR GRINDING AND CHOPPING MEAT AND VEGETABLES must be kept free of corrosion and deposits. Every month the electric motor must be inspected for loose parts that could cause vibration, for dirty contacts, for breaks in insulation, and for other defects.

Annually, this type of equipment must be inspected for corrosion, particularly on metal surfaces in contact with food, and for electrical faults. At this time, the insulation resistance of the motor windings should be tested with a 500-volt megger; a reading of less than 1 megohm indicates some electrical defect, probably a break in insulation, or moisture in the windings. Moisture can be dried out by oven baking; then apply insulating varnish, and retest.

VEGETABLE PEELERS are another type of galley equipment operated by electric motors. The peelers must be kept in a level position to prevent excessive vibration. The bearings must be lubricated, the water piping and drains kept free of leaks, and abrasive disks replaced when they become worn smooth. The electric motor and drive should be checked monthly for clearances, belt tension, and moisture. Rust and deposits should be removed, and bare spots touched up with nontoxic mineral oil.

Once a year, the motor should be completely dismantled, and a check made of insulation, clearances, and alignment. The motor windings should be tested with a megger, as in the case of meat and vegetable choppers and grinders.

Motor-driven FOODMIXER AND CAKEMIXER EQUIPMENT will probably be found at any large installation. Such mixers must be in alignment, with proper clearances, and with all bolts and moving parts tight enough to prevent undue vibration. Rust or corrosion on metal surfaces must be removed with solvents, and the bare spots treated with petroleum jelly or mineral oil.

Each year, the equipment should be disassembled, and all parts checked for corrosion, alignment, clearances, and for any type of electrical fault.

DISHWASHING MACHINES

The Navy uses two types of dishwashing machines: an automatic double-tank type for large installations, and a semiautomatic single-tank type for the smaller installations. Figure 6-4 illustrates an automatic machine, and figure 6-5, a typical machine of the semiautomatic type. The identification of the various parts should give you a very clear idea of the method of installation, and also be of help to you in following the prescribed maintenance procedures. See pages 210 and 211.

In the automatic type, washing and rinsing are continuous as long as the machine is in operation. In the semiautomatic type, the washing spray alternates with the rinsing spray, and their duration is automatically controlled.

Both the upper and lower spray assemblies must be in correct position, to ensure that both the fronts and backs of dishes will receive the jets of water, and that the wash water and the rinse water will not splash into the wrong tank. Spray slots and nozzle openings must be free of obstructions. Splash curtains for automatic dishwashers must be free of tears and holes.

Conveyor chains must be checked for possible defects. If they are loose, reset the tension adjustment device, so as to prevent noisy operation. Speed of the conveyor must allow for a 20-second exposure of the dishes to the rinse water, and if possible a 30- to 40-second dish exposure to the wash water spray.

Maintenance and Repair

Good maintenance procedures should include periodic inspection of dishracks, rack trucks, and other accessories for any signs of deformation or defects. Check the wheels to see if they have flattened, and look for any loose parts, or structural defects.

From time to time, you may be called upon to adjust dishwashing machines that are giving the operator some trouble. The most commonly occurring difficulties, the usual reasons for their occurrence, and the remedy for them, are suggested in the following trouble-shooting chart:

Minor Repairs on Dishwashing Machines

Trouble	Cause	Repair
1. Dishracks slide off chain conveyer.	Incorrect tension on either chain.	Reset idler sprockets on each chain to proper tension.
2. Insufficient water pressure at spray nozzles.	Plugging of spray nozzles, or slot.	Dismantle spray assembly, wash out piping with hot, soapy water, clean slots and nozzles with brush, or if necessary, replace nozzles.
	Plugging of strainer baskets.	Remove the cleanout plug, and then the strainer basket. With a brush and hot, soapy water, wash out the basket, giving special attention to the perforations.
	Slipping belts on pumps.	Replace old and wornout belts. If belts are still serviceable, adjust tension by resetting the idler pulley, or by moving the sliding base of the motor.
3. Water is entering the wrong tank, or is splashing on the floor.	Sprays out of position.	Adjust the spread of the water spray so as to keep the stream within the tank limits.
	On automatic dishwashers, curtains torn, or not in position.	Repair curtains, or adjust them so that the bottoms are about 5 in. above the rack.
	On semiautomatic dishwashers, leaks around the door.	Replace the gasket around the door. Check the door for warping or misalignment. Check the counterweights, to see if they are in operating condition.

Minor Repairs on Dishwashing Machines—Continued

Trouble	Cause	Repair
4. Rinse water temperature is less than 180 F.	Booster heater is not giving sufficient heat.	For electric heater, check for blown fuse, loose wire; replace element if necessary.
		For gas-fired or gasoline unit, check fuel supply, and adjust fuel-air mixer to give blue flame.
		For steam-coil or steam-injection unit, inspect for leaks and low steam pressure, and make the necessary repairs.
		Check the automatic temperature controls for defects or wrong setting and make any required adjustments.
5. Film on eating utensils after final rinse.	Wash water is saturated with grease.	Make sure that the wash water is drained periodically, and a fresh detergent solution provided.
	Improper detergent mixture.	Soft water detergent is being used with hard water; or the detergent is insufficiently dissolved, because water temperature is below 140° F.
	Insufficient time for washing or rinsing.	On automatic machine change conveyor speed; on semi-automatic, reset timer.
	Weak sprays, or sprays in wrong position.	Clean nozzles, spray pipes, strainers, and scrap trays; check the piping for leaks; see that valves are fully open; check the pump for noisy operation.

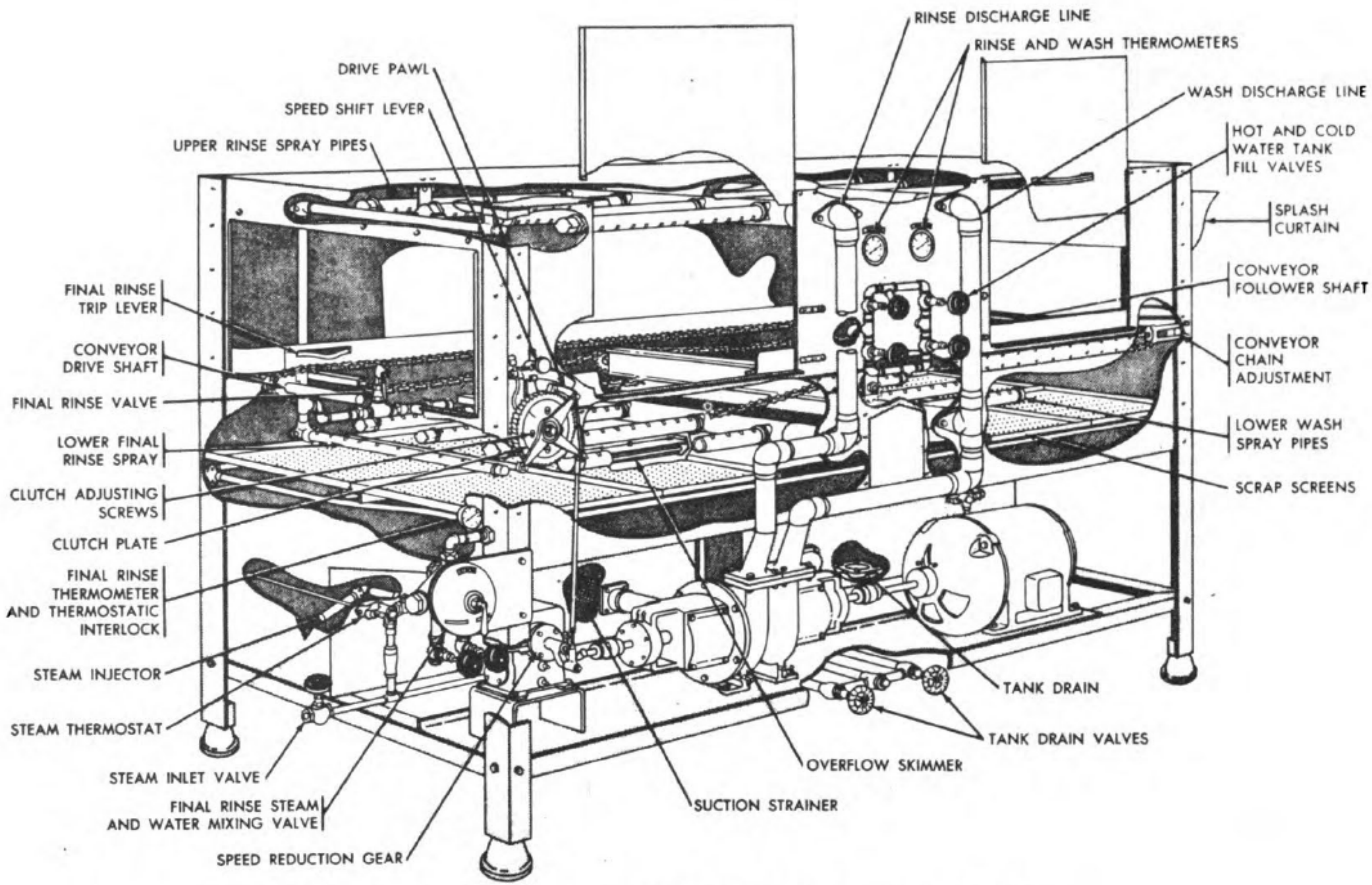


Figure 6-4.—Automatic dishwater, with two tanks.

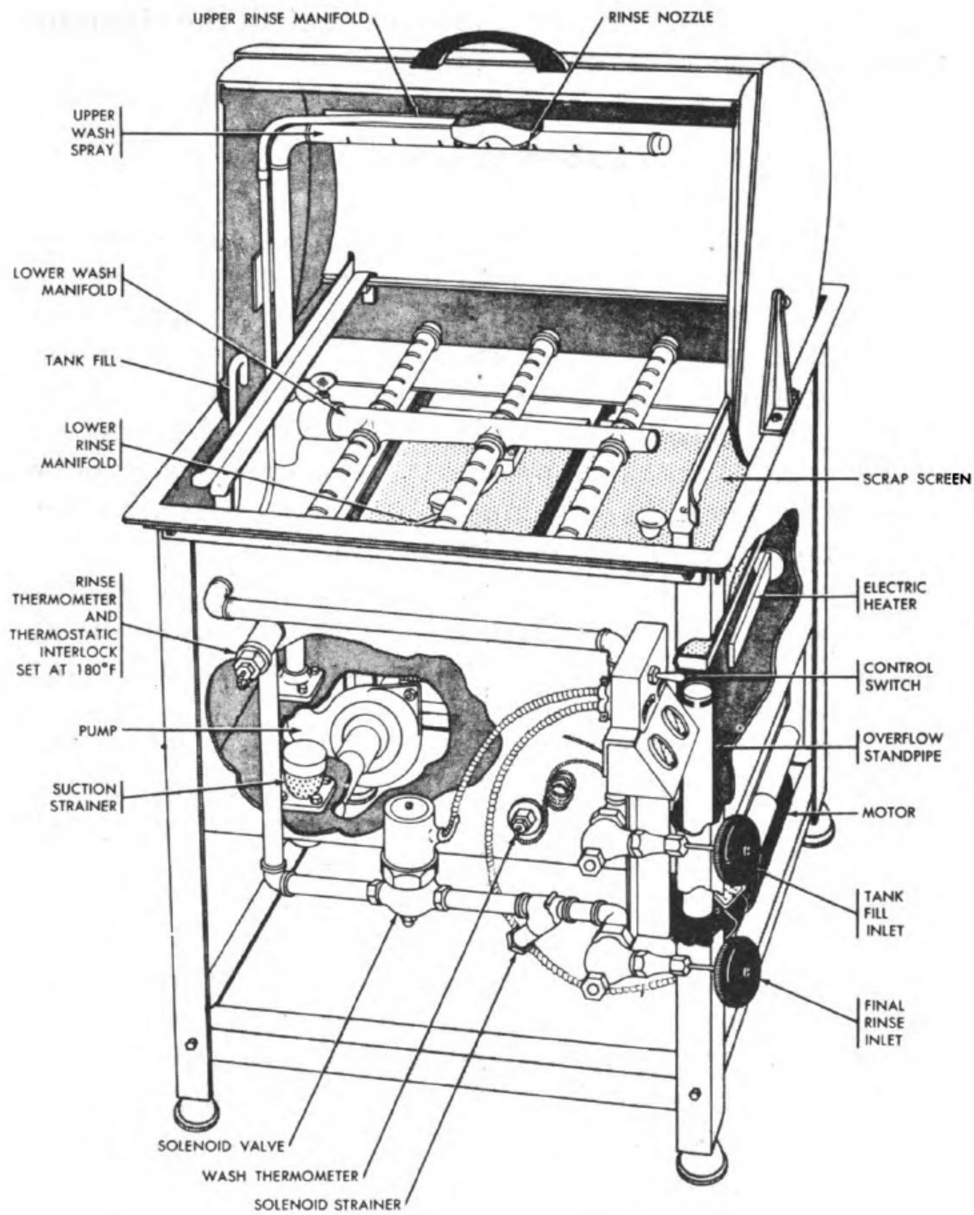


Figure 6-5.—Typical semiautomatic dishwashing machine.

Descaling to remove deposits from within the machine, as well as in piping and pumps, is done by filling the tanks half-full with hot, clean water, adding a cleaning solution, filling the tanks to overflow, and then operating the machine for 30 minutes, at high temperature, and with scrap trays, spray arms, and curtains in place.

After this period of operation, you should drain the tanks, fill them with hot water, and run the machine for 5 minutes. This rinsing procedure should be repeated

several times, in order to make sure that all the cleaning solution has been removed.

Lubrication

Lubrication of the dishwashing machines, like that of all galley equipment that comes into contact with food or with eating utensils, must be done with a lubricant that will not deteriorate or grow rancid. It is best to use an unsalted, colorless mineral oil, or petroleum jelly, spread to form a light film over the lubricated surfaces. Ordinary petroleum oils and lubricating greases can be used where there is no danger of food contamination from deterioration of the oil or grease.

Lubricants should adhere to surfaces without dripping, should retard acid or alkaline action, should not emulsify if exposed to water spray, and should be suitable for operating temperatures, speeds, and pressures.

The points that chiefly require lubrication are: grease cups on pump shaft bearings, on the drive end of the conveyor, and on the rinse lever. The revolving wash arm should be lubricated occasionally.

Lubricate the parts of the machine only when necessary, and never while the machine is in operation.

With regular inspection and lubrication, with repairs and adjustments made as needed, and with strict observance of manufacturers' operating instructions, these machines are capable of a long period of satisfactory service. To make sure that they have the required attention, set up a regular schedule for weekly, monthly, and annual inspection.

Inspection Schedule

Monthly inspection and maintenance should include:

1. Check of the lubrication of bearings, gearboxes, chains, sprockets, and so on.

2. Check of electrical equipment, such as motors, fuses, electrically controlled temperature-regulating devices.

3. Check of the alignment and tension of drives—V-belts, flexible couplings, chain-and-sprocket.

4. General check on level; check for misalignment of components, for loose parts, for unusual noises.

Annual inspections should include:

1. Check on frames, for adequacy of support; tightness of casings, seams, joints, counterweights; evidences of corrosion; watertightness of doors, hinges, gaskets; and correctness of clearances and alignment.

2. Check motors for condition of V-belts, sprockets, gears; condition of insulation (use megger test); clearances between stator and rotor; evidences of wearing of rotor or shaft; cleanliness of commutator brushes; and ventilation (casing, base, airports).

3. Check pumps and impellers, for possible corrosion or extreme wear of any of the parts. Disassemble them, clean all parts thoroughly, and repair or replace badly worn shafts, bearings, or water-seal packings. Reassemble and adjust. Lubricate wash water pumps, and rinse water units.

4. Check all the various systems (water, steam, electric, gas, waste) for leaks and obstructions. Check the piping supports, and the operating condition of pressure gages, valves, switches, and contacts.

ICE MAKERS

A discussion of this equipment might have been included in the chapter on Refrigeration, except that ice making plants operate with a different type of refrigerant, and employ a somewhat different process.

Large plants are those in which the ice-making capacity is from 10 tons daily up to as much as 50 tons. However, where need for ice is nominal, small plants, either automatic or semiautomatic, may be installed.

The refrigerant most commonly used is ammonia. Direct expansion of the ammonia in a brine cooler (or in coils immersed in a brine tank) cools the brine. To promote rapid heat transfer, the brine is circulated by an agitator. The operation of the agitator should be continuous while the ice plant is in use.

The ice is made by placing cans of water in the circulating brine; to produce clear ice, the water in these cans is agitated by compressed air during the freezing period.

An adjacent insulated space should be provided for the storage of the ice.

Evaporative condensers conserve water for condensing purposes, and the use of two compressors, one 50 percent smaller than the other, permits capacity variation. That is, with only the smaller compressor operating, you obtain 33 percent of total possible load. With the larger compressor operating, you obtain 67 percent of total load. With both compressors in operation, you obtain 100 percent total load.

Even where there is an ample supply of ice in storage, the ice cans must be kept filled while the plant is running. Otherwise, the brine level in the tank will be lowered, resulting in poor operation of the equipment. Be careful not to spill water from the ice cans into the brine.

Proper maintenance requires monthly inspection of these ice plants, with a test of pH value and density of the brine.

QUIZ

1. Soot and dust that form external deposits on the steam coils and finned-tube elements of a steam heating unit should be removed with
    (a) a cloth dampened in water
    (b) an emery cloth
    (c) a pointed stick
    (d) a vacuum cleaner
2. If, in testing the heating element of a heating unit, you find a cool spot, what is the probable cause?
3. Where do you check the voltage on an electric range? The amperage?
4. What is the preferable device for cleaning the electrical contacts of a heating unit?
5. Replace an oven thermostat if you find that you cannot adjust it to within at least
    (a) 3 F of preset temperature
    (b) 5 F of preset temperature
    (c) 10 F of preset temperature
    (d) 12 F of preset temperature
6. How often should oven assemblies be disconnected from the power supply, and checked for defects?

7. What is the preferred way of removing carbon deposits on the heating elements of griddles?
8. When as much as 30 percent of the orifices of a gas burner have become choked by insoluble deposits, what should you do?
9. What is the purpose of the pressure-reducing valve on a vegetable steamer? The blow-off valve?
10. When a plunger-type valve is installed on a vegetable steamer, how should the plunger be adjusted to allow a full complement of steam to enter the steamer?
11. What action should be taken when a safety valve on a steamer is found to be defective?
12. Vegetable steamers should be inspected for possible need of repainting, and for evidences of rust and corrosion, at least
    (a) monthly
    (b) quarterly
    (c) semiannually
    (d) annually
13. When steam between the jacket and kettle skins of a steam-jacket kettle exceeds safe limits, it is released through the
    (a) steam drain
    (b) exhaust outlet
    (c) safety valve
    (d) draw-off faucet
14. How is the calibration of a steam gage on a steam-jacket kettle tested? The calibration of a thermostat?
15. Why is the use of oil-fired units for a steam table to be avoided whenever possible?
16. At least once a year, the insulation resistance of the motor windings on motor-driven meat-and-vegetable grinding machines should be checked with
    (a) a 100-volt megger
    (b) a 500-volt megger
    (c) a 1-megohm meter
    (d) an ammeter
17. What treatment is recommended for bare spots on motor-driven foodmixer equipment?
18. Why is it important that the upper and lower spray assemblies of dishwashing machines be properly positioned?
19. What 4 qualifications does the text indicate for lubricants used on dishwashing machines?
20. How often should the pumps and impellers of dishwashing machines be checked for signs of severe wear or corrosion?

21. The refrigerating agent most commonly used in ice-making plants is
    (a) ammonia
    (b) brine
    (c) compressed air
    (d) Freon-12

22. What is the advantage of having two compressors installed in an ice maker?

CHAPTER 7

WATER SOURCES

Next to air, water is the most essential element for survival. We take water as a matter of course, because we are accustomed to turning a faucet, or starting a pumping mechanism, and getting water in the desired amount, and of a quality consistent with the purposes to which we will put it. The Utilities Man, however, may have to face the problems that arise in primitive communities. If he is to provide a supply of water sufficient for the needs of an installation or of a battalion, he should have a knowledge of the natural sources of water, and the methods of purifying it for safe use.

The rainfall and water cycle comprises the evaporation of water from the oceans of the world; its condensation in the atmosphere; its precipitation in the form of rain, sleet, snow, fog, hail, or mist; its dissipation by surface runoff, evaporation, absorption by the roots of vegetation, and infiltration into underground layers; the movement of this underground water through various strata; and the reappearance of underground water at the surface, in the form of springs, lakes, and so forth.

Our practical concern with water begins at the point of its precipitation upon the land surface. The proportion of this water that is lost through subsequent evaporation, and to the roots of vegetation, is relatively minor. The greatest part will be impounded in natural bodies of water on the land surface, or will percolate through the soil until it is collected beneath a certain level called the water table.

Whereas the water that collects in streams, ponds, and other natural reservoirs can normally be made available for use in the immediate area, water that seeps down to underlying layers may be lost to the area that received the rainfall, or other precipitation, if subterranean channels permit its escape to another drainage area.

The water supply of a given area, therefore, may be said to depend upon the supply received as precipitation, the extent to which there exist natural or artificial basins that can store it against future use, and the geology, or underlying contour and composition, of the particular region. For all practical purposes, the amounts lost in evaporation and in absorption by vegetation can be disregarded.

The supply received as precipitation, usually in the form of rainfall, depends upon the rate of precipitation in a single storm (or a closely connected series of storms), and the frequency with which precipitation occurs. The sources from which you can obtain this type of data are discussed later in this chapter, in the section on water reconnaissance.

TYPES

The types of water available in most communities will be those located on the land surface, and those that are underground but can be tapped for use. In addition, on island installations or at sea coast installations, there is a possibility of using sea water, if it can be distilled. The methods by which distillation can be effected are taken up in the following chapter. This chapter is confined to a discussion of water that can be obtained from aboveground or underground reservoirs.

Surface Water

We may define surface water, for the purposes of this chapter, as any water flowing in streams or rivers, or resting in ponds, lakes, or other reservoirs, either natural or artificial. Such water may be from the precipitation from the atmosphere; it may be underground water which has forced its way to the ground surface; or it may come from a combination of these sources.

A water supply may be derived from surface water by gravity, by pumping directly from streams, ponds, or lakes, or by collecting water from springs. It is also possible to build cisterns or other basins for collecting rainfall and other forms of precipitation. Where surface water runoff is rapid, dams can be built to impound these waters.

Where natural bodies of water are to be used as a source of supply, intake or outlet screens should be constructed. In taking water from a stream, be careful to place the strainer at a point where the water is deep, and as clear as possible. The location of the intake strainer must always be upstream from any bathing or animal-watering facilities. The strainer should extend at least 6 inches below the stream's surface; it should not rest upon the bed of the stream, nor should it be so near the surface that air and floating matter will be drawn into the suction pipe.

It may be necessary to dig a pit for the strainer, if the stream is shallow. Line the pit with gravel, as illustrated in figure 7-1, to prevent an accumulation of dirt or silt, which could clog the strainer, or enter into the distribution

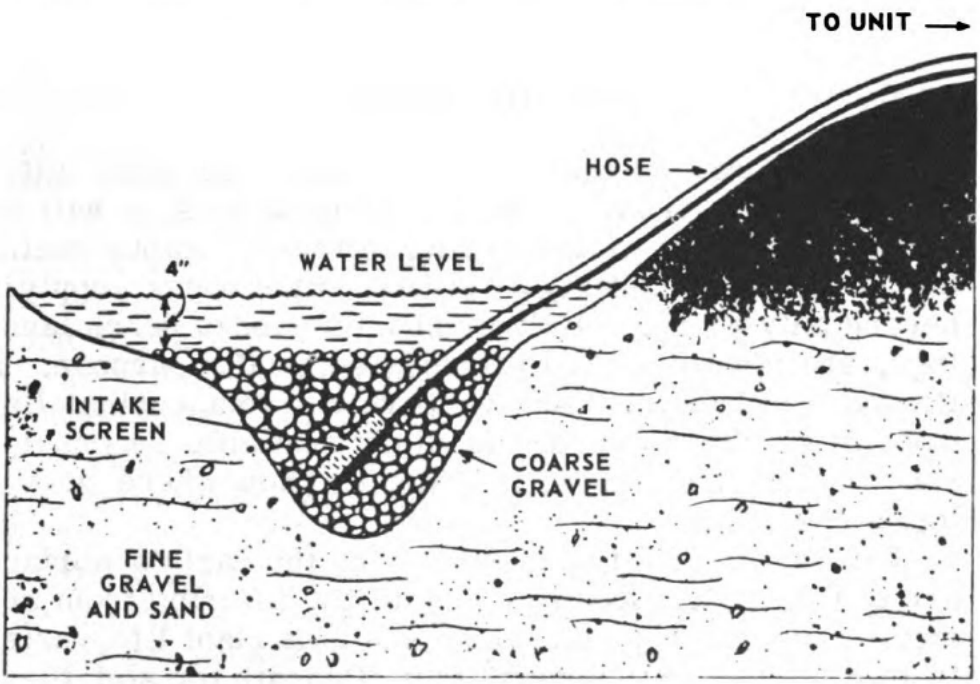


Figure 7-1.—Use of gravel to protect intake strainer from dirt accumulations.

system. The strainer should rest upon a layer of gravel, and be covered with another layer, as indicated. If the stream bed is silty, place the strainer in a sunken bucket.

The methods of tapping surface waters are fairly simple, but the waters themselves are usually in need of artificial purification before they may safely be put to use. Natural water may contain almost anything in solution—chemical compounds, or microscopic plant or animal life. Rainfall washes soot, dust, and even organisms out of the atmosphere, and dissolves gases normally present there. Decaying organic matter on the earth's surface will charge surface waters with products of decomposition. Further pollution of water may occur from sewage drains that have been carelessly located.

Water from swift streams or from large lakes may be so slightly polluted as to require only chlorination. Lakes or streams that are slightly turbid can be treated by filtration, or by coagulation plus filtration. However, it is always prudent to assume that surface waters are contaminated with bacteria and other impurities, and may be a source of disease unless they are subjected to some purification process. How to test for the quality of water, and how to purify it for safe use, has been discussed in detail in chapter 8 of NavPers 10656-C.

Ground Water

Where it is not possible to develop an adequate water supply system from existing surface waters, it will be necessary to drill wells in order to recover ground water that is stored in underlying strata. If the water supply is needed only for the relatively short period of beach landings, shallow wells will probably serve the purpose. If the water is required for a relatively permanent installation, it will be necessary to study available reconnaissance data for the area, in order to know where best to locate the wells.

The layers, or strata, underlying the earth's surface are of various composition and depth, differing from region to region. Top soil, which sustains plant life, varies from a few inches to several feet. Beneath top soil, there is generally a layer of firmer soil, then an intermediate layer of decomposed rock, and finally the solid rock itself.

The layer of decomposed rock has been acted upon by a number of influences: earthquakes, volcanic action, chemical reactions, pressure conditions, and so forth. During the ages, these influences have resulted in producing anything from semisolid rock to a conglomeration of sand, gravel, and broken stone. In many regions, the solid rock has been converted to softer materials such as limestone, dolomite, and silica.

This description of the successive layers is a generalized one, not true for all geographical areas. In the course of geologic periods, these strata have been bent, folded, and broken to such an extent that their specific courses cannot be charted here.

Usually these layers follow the general contour of the earth's surface; however, they may outcrop at the surface, or may slant downward in different directions. In some locations, solid rock may outcrop at the surface, with no overlaying soil, or mixture of soil and decomposed rock.

The STORAGE AND PRODUCTION of ground water is affected by the composition and relative position of these various strata. The layers may be of a type that will permit water to percolate through them, or they may form an impervious bed upon which the water will flow in one direction or another.

Most of the water that penetrates beneath the ground surface follows a general downward course along the path of least resistance. When underground water is stabilized, either because it is held by an impervious rock layer, or because the amount percolating from above balances the amount flowing away laterally, the water table for that particular locality is established. The level of this water table will fluctuate according to the varying amounts received from precipitation (the influent) and the rate of withdrawal (the effluent).

The level of the water table is not a flat surface, as it would be aboveground. Generally, it will roughly coincide with surface topography; however, it depends upon the configuration of the area in which it can accumulate. Since this area must be underlain by an impervious stratum, and be permeable (or porous) itself, the water table may take any shape. The water retained in the area may even flow uphill, if the pressure of the influent supply is

sufficient to force the main body through pervious layers of soil and decomposed rock.

If an impervious stratum which outcrops at the ground surface forms an underground obstacle to the water table, a spring will usually result at the point of outcropping. The water is prevented from flowing forward, and under the pressure of additional amounts being added, it will percolate upward through the thin soil layer.

Figure 7-2 illustrates a water table with uphill flow, and the occurrence of a spring caused by the outcropping of an impervious stratum. It also shows how rainfall precipitated upon one area may escape underground to another area. The fact that this figure has been drawn to illustrate both these factors in relation to a water table does not mean that the factors are frequently associated.

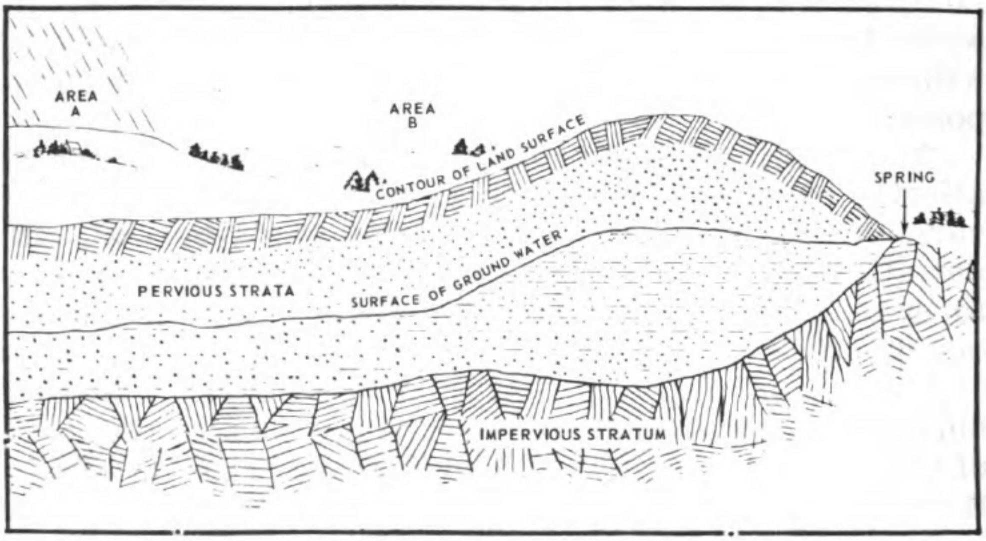


Figure 7-2.—Formation of a water table.

Other Sources

In tropical areas especially, water may be supplied directly from heavy rainfalls. It may also be recovered from the type of fresh water deposits that rest upon a salt water surface, as described later in this chapter, in the section on Maui wells.

During limited occupation of a site, or in an emergency, fresh water can be recovered from SEA WATER by the process of distillation. This, however, is an

expensive method, and not to be used where water supplies can be obtained by the more usual processes.

In regions of heavy tropical rainfall and rapid runoff, rainwater can be collected from the roofs of buildings, and conducted to cisterns in which it can be stored for distribution. Collecting surfaces may be wooden or metal gutters, or tarpaulins supported on poles. The surfaces must be elevated, so that the water will drain into the tanks or catch basins. These tanks and cisterns must be kept covered, to prevent any avoidable contamination of the water.

Special CATCHMENT BASINS can be constructed in tropical areas, to catch the rainfall from the short but frequent showers that customarily occur. The sides of hills can be cleared, graded, and then given a surface application of cement or similar impervious mixture. These catchment areas should be located so that the water collected will be diverted downward to a central point or points, where suitable storage systems have been provided.

RECOVERY OF GROUND WATER

Any stratum which contains ground water is known as an aquifer (water-carrier). The adequacy of the supply and the maximum rate of withdrawal, at any specific location, depend upon the porosity and the permeability of the water-bearing stratum.

Porosity is the property of a stratum to absorb water, and is therefore closely related to supply. Permeability (or perviousness) is the capacity of the stratum to transmit water under pressure, and is therefore related to availability. A highly porous material, such as clay, may be practically impervious; on the other hand, an igneous rock, only 1 percent porous, may yield all the water that it contains.

Ground water appears principally in one of the three following forms:

1. In porous strata where the rate of percolation and the resistance to free flow of the underground water combine to maintain a reservoir of ground water well above the elevation of the natural outlet at ground surface.

2. Water held in the channels and spaces of porous rock, or buried under pervious strata.

3. Water in buried river valleys, or in the beds of ancient lakes.

Where water is held in a porous stratum underneath an impervious one, it is often subject to a pressure that is greater than atmospheric pressure; if it can find an escape passage to ground surface, it will form an artesian spring. If there is no escape passage for this type of ground water, it can be tapped by a drilled well. The water may rise to ground level, and the well will flow. This type of well is known as an artesian well. If pressure on the underground reservoir is not sufficient to bring the water up to the surface, it will at least cause the water to rise a considerable distance in the drilled well, and pumps can be used to bring water to ground level.

Sometimes the water held in a cavity above an impervious layer is of such limited quantity that it is quickly exhausted. For example, there might be a cuplike cavity in a rock formation, above the level of the established water table for the area. Water collecting in this cavity is prevented, by impervious strata beneath, from flowing to the real water table, and so establishes a false water table. This is what is known as a perched supply. Once the supply has been exhausted, it can be replenished only by seepage from above; perched water, therefore, never constitutes a dependable water supply.

Springs

The conditions that cause the formation of springs are varied, but all springs, however formed, produce an overflow of ground water upon the land surface. When it is desired to collect these waters, the particular conditions that caused the springs become very important, since these conditions are factors in constancy of flow, and probable existence of similar springs in the nearby area.

Springs are usually one of the three following types:

1. Outcrop type, in which water is brought to the surface in an aquifer which is underlain by an impervious strata which outcrops and forces the water out as a spring. This type of spring has already been mentioned,

and is illustrated in figure 7-2. Outcrop springs are probably the most common, but flow from them is likely to be uncertain.

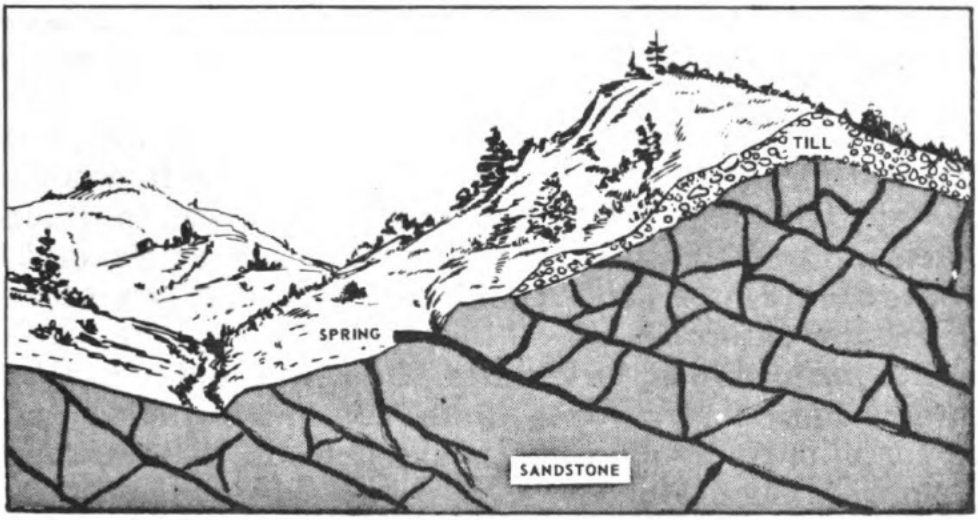


Figure 7-3.—A fracture spring.

2. Artesian type (already described), where an impervious layer overlays the aquifer. The water may reach the surface at a point where the impervious layer is so thin that it cannot resist the upward pressure of the water. Sometimes, the water escapes through fractures in the rock, as illustrated in figure 7-3.

3. Overflow type, where the carrying capacity of the porous stratum is insufficient to handle the entire tributary flow. This type of spring usually appears in several places in a localized area, and a surface flow (brook or small stream) may form. The character of the water from such sources will differ from that of most ground water, since the water will have picked up some impurities in its travel over the ground surface.

When it is desired to use the water supplied by a spring, the best method of collecting is to build a cutoff trench located near the spring and following the contour of the surface. The deeper the trench, the better the chance of a continuous flow.

Yield from an outcrop spring is likely to vary; yield from the flow type of spring is liable to very great fluctuation; but yield from an artesian type of spring may be practically invariable. These latter springs are but

slightly affected by variations in rainfall; the amount of reserved water varies with water table level, in the area of percolation, but the spring itself may be miles distant from the rain fall area, and this tends to stabilize yield.

When a spring is on a hillside, it is necessary to take precautions against contamination of the water by surface drainage from the higher areas. Earth dikes can be constructed in the form of a V, to straddle the spring, and divert drainage flow from higher ground. The flow from the spring can be collected in boxes, tarpaulin lined holes, concrete basins, or similar types of reservoirs. These basins must be kept covered to prevent contamination of the water.

All springs must be cleaned before the water can be safely used. Undergrowth, loose soil, rocks, sand, and so forth must be cleaned away, and any surrounding swampy areas drained.

Wells

Where no surface water supply is available, and no springs occur, the water table must be tapped by means of wells. The history of wells as a means of obtaining water supply goes back to antiquity, but the centuries have brought advanced methods into use, and the only dug wells nowadays are shallow wells. Most modern wells are of the drilled or cased types, although local conditions may indicate the construction of a radial (or ranney) well, or of the Maui-type well so widely used on the islands of the Pacific.

The success of a dug well depends upon whether a water-bearing stratum can be reached at a reasonable distance from the ground surface. These wells are very rarely dug to a distance of more than 40 feet; a depth of 20 feet or less is much more common.

In some locations, test holes will indicate that there are numerous water-bearing strata, all of comparatively small flow, and separated by thin, impervious strata. Although no single aquifer is of sufficient thickness to provide a serviceable water supply, it may be possible to penetrate and collect water from several aquifers.

DRILLED WELLS have been commonly used for several centuries. Essentially, the well is produced by

concussion, or else by a machine-driven rotary bit capable of chipping away the underlying rock formations. The holes are drilled until they reach an aquifer that is capable of (1) supplying the required quantity of water, at the desired rate of flow, and (2) supplying the required amounts of water without noticeable lowering of the water level in the well.

When drilling begins, the loose earth and broken rock are removed from the hole by the use of specially constructed buckets. Samples should be taken to determine the points where a change of stratum occurs. By introducing water into the hole, you can soften the waste material, or else hold it in suspension, so that it can more easily be picked up by the buckets.

A careful record should be kept of the material samples, so that the log maintained on the well will show the nature and the thickness of the various strata encountered and the depths at which they occur. Tests must also be made of the water supplied by each aquifer, to ensure that no polluted source will be allowed to feed into the well.

When suitable aquifers are encountered, screens as long (or longer) than the depth of the aquifer are constructed and placed in position. These screens are provided with slots that will allow the desired amount of water to flow into the well. After all preliminary tests have been completed, the well is first pumped free of sand, and then a permanent water pump is installed.

Since it is important that the well itself be clean and free from water-polluting characteristics, it is usual to line or case the sides of these wells. Casing also prevents possible cave-ins, and seals off polluted water aquifers occurring above the level of the aquifers to be used.

Occasionally it happens that the maximum yield from a well can be obtained by proper selection of openings in the water screen, without any trouble. This is because the materials forming the aquifer contain just the right proportion of coarse and fine aggregates, and consequently there is no movement of sand into the bottom of the well.

More often, however, some arrangement must be made to prevent the accumulation of sand and fine materials. The usual method is to wash this material out of the

bottom of the well under water pressure, at the same time introducing gravel in its place. This gives you the type of gravel-packed or gravel-screened well that is typical of many of the modern wells. Figure 7-4 illustrates how these gravel-packed wells are constructed.

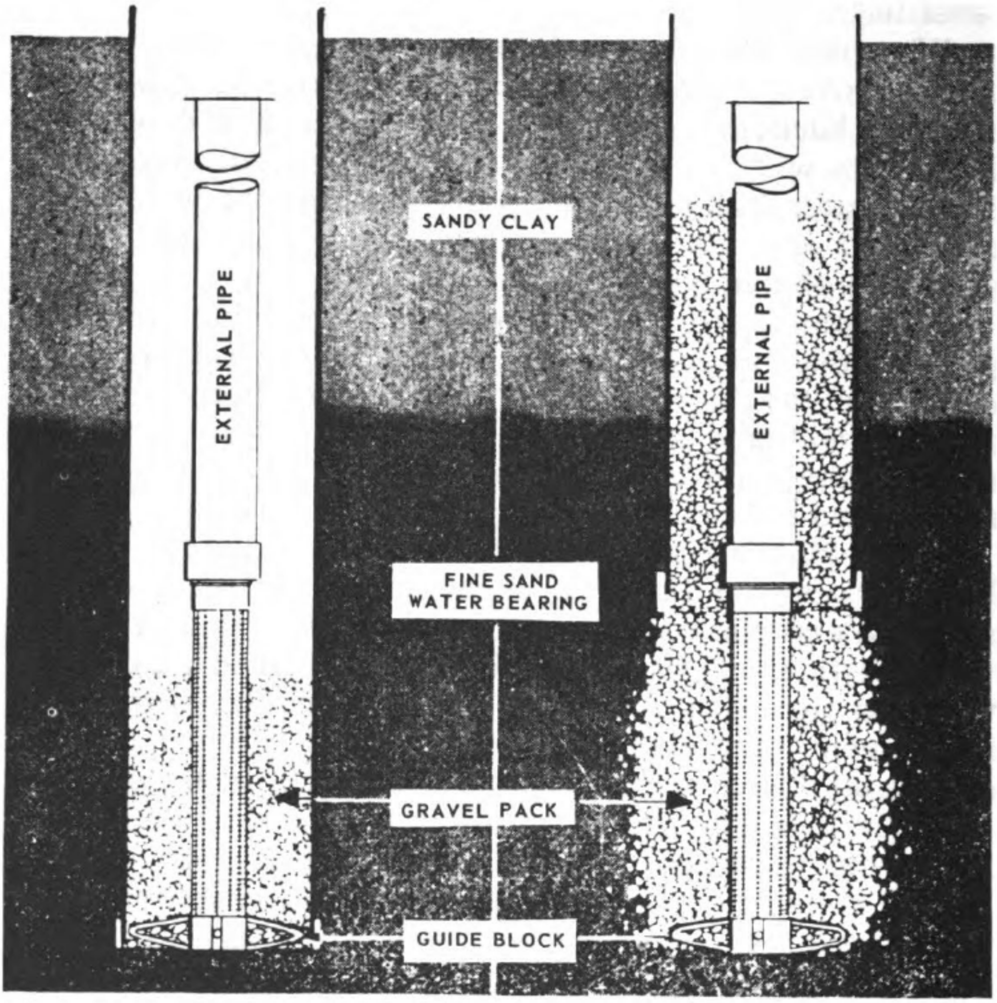


Figure 7-4.—Gravel-packed well: with casing in place, and with gravel wall completed.

OPEN END WELLS are those in which it is not necessary to install screens, and the water is allowed to freely enter the open bottom end of the casing. These wells may be either bored or driven wells. Bored wells are excavated by hand-driven or power-driven augurs; driven wells are those in which the casing is equipped with a drive point, or sand point.

Failures of wells can usually be traced to faulty construction or to poor operational methods. Entire well fields have been lost because of the use of wrong materials, or of improper spacing, or of pumping rates in excess of safe yield.

RANNEY WELLS are a new and interesting development; they can be used only where the location favors this type—for example, in gravel beds close to surface streams and rivers.

A shallow, open well is excavated to expose an aquifer, and then a number of horizontal wells are driven into the aquifer. Because of its type of construction, the ranney well is frequently referred to as a radial well. The horizontal wells conduct water from the aquifer into the central collecting basin, which is lined with brick or concrete. Screens and perforated pipe sections may make up a large section of the horizontal wells.

MAUI WELLS may offer the best solution to water supply problems on small islands, where the population must depend upon precipitation to meet their water needs. The water that percolates to the underlying strata does not mix with salt water at the sea level zone, but adjusts itself into a lens-shaped body that rests upon the surface of the salt water. So long as no agitation or stirring takes place, the difference in specific gravity between salt water and fresh water will operate to keep them separate.

In this lens-shaped body of fresh water, the upper face of the lens is of shallow convex shape, and lies wholly above the line representing sea level. The lower part of the lens is of a deep convex shape, and lies wholly below sea level. Both the fresh and the salt water are being held in suspension in the voids of the rock or soil formation in which they rest.

The type of formation that supplies a Maui well is illustrated in figure 7-5. The well itself is an inclined shaft, sunk at an angle that will allow access to the fresh water lens with a minimum of digging. At some point below the fresh water line, a horizontal tunnel is constructed. A catch basin at the bottom of the inclined shaft receives the water from the lateral tunnel (or tunnels).

The horizontal tunnels provide for drawing off the water near the surface with a minimum of disturbance,

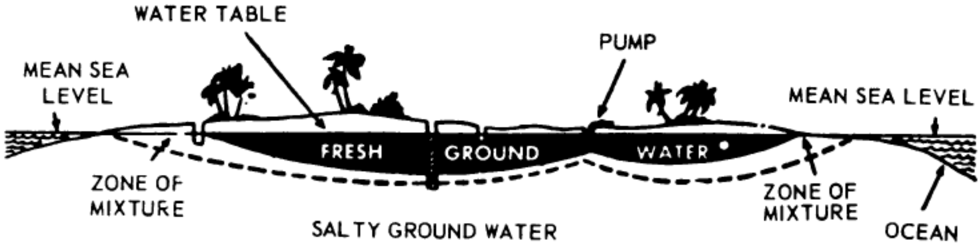


Figure 7-5.—Formation that permits development of a Maui well.

and consequently with a minimum mixing of salty and fresh water. Pumping facilities and piping are installed at the catch basin, to raise the water to the land surface, and feed it to whatever distribution system has been arranged.

It takes 40 feet of sea water to balance 41 feet of fresh water, so that there are 40 feet of fresh water in the lens below sea level for 1 foot of fresh water in the lens above sea level. If fresh water is skimmed off the surface of the lens at a greater rate than that of replenishment from above, the well may soon be exhausted. With the removal of each foot of water above sea level, the bottom level of the convex lens is raised 40 feet. Geologists have estimated that when once a fresh water supply of this type has been exhausted, it may take as long as 50 years to replenish it; in some cases, it may never be restored.

WATERBORNE DISEASES

A surface water supply may become polluted, and become the source of waterborne diseases, because of micro-organisms brought down from the upper atmosphere, plant or animal organisms picked up by the water from ground surface, and contamination from drainage. Microscopic plant and animal life is sometimes brought down out of the atmosphere by rain, and may become a source of disease. Plant and animal organisms in surface waters may render those waters unsafe for drinking. Pollution of water because of careless arrangement for sewage drainage could easily become the cause of epidemics. The greatest emphasis must be placed on careful selection of water supply in the first place, and its treatment and safeguarding after selection.

Fresh surface water (and ocean surface waters also) contain floating organisms, both plant and animal life, called plankton. These vary over a wide range in size; the dwarf plankton are only slightly larger than bacteria, whereas the net plankton are large enough to be visible to the naked eye.

Plant life types include fungi (yeast and molds) and algae (red, yellow, or green). Some of these algae are odor-producing.

Animal life types include single cell protozoa and metazoa; some of these organisms are visible to the naked eye. Of the protozoa, some varieties of amoebas indicate gross pollution of the water. The flagellate protozoa (organisms with slender, whiplike extensions) are odor-producing organisms, and their presence may be expected in all surface waters. Of the metazoa, several species of a larval form, known as cercariae, may cause christosome dermatitis, or "swimmers' itch." These christosome cercariae pierce the skin, and in a few minutes itching begins. However, the organism does not enter into the bloodstream, but eventually dies in the skin layers. Cercariae of blood flukes can cause serious illness, however.

If the various organisms found in natural water caused nothing more than personal discomfort, they would still be a liability to general wellbeing and efficiency of personnel. Many of them, however, can cause serious illnesses, which may become epidemic. The effects do not appear immediately after the consumption of the contaminated water, but only after a delay known as the incubation period. This period varies from 2 or 3 days to as many weeks, according to the bacteria or the amoebas that cause the disease.

A brief discussion of the various waterborne diseases that may spread if proper attention is not given to water supply will help to stress the importance of continual care and inspection.

Typhoid

Typhoid fever is an intestinal disease, caused by a waterborne bacterium (bacillus typhosus). The vaccination given every military man protects him to a degree

against this disease, but the protection is not absolute, and can be nullified by the consumption of contaminated water. Fortunately, this bacillus can be readily destroyed in the water by the application of field chlorination procedure.

The disease manifests itself in a rose-colored eruption of the skin, accompanied by a high fever, and frequent bowel movements. The organisms are present in the waste from the bowel movements, and can contaminate a water supply into which this waste material might seep. The disease organisms will not multiply in the water, and for the most part die within a week. However, the colder the water, the longer they live; in ice, they may live for as long as 3 months.

The incubation period for typhoid varies from 3 to 40 days, with the average time being 7 to 10 days. Recovery from an attack usually (though not always) results in permanent immunity.

Paratyphoid

Paratyphoid is similar to typhoid in sources of infection and in symptoms; the organisms are, like the typhoid bacillus, readily destroyed by field chlorination methods.

The incubation period varies from 4 to 10 days. An attack gives a man immunity from a second attack of paratyphoid, but does not give immunity from typhoid.

Cholera

Cholera is an infectious intestinal disease marked by violent spells of vomiting, cramps, rapid evacuation of the bowels, and a subnormal temperature. The cholera germs discharged from the body in the feces will live for several days; if water comes into contact with this human waste matter, the germs may live for weeks, and may even multiply.

Contaminated water is the most frequent means of spreading this disease, although it can also be spread by food, and by contact with an infected person.

The incubation period is usually about 3 days, but the disease has been known to strike a man within a few hours of his drinking contaminated water. Only about

one-half the cases of cholera recover, and these have no assurance of anything more than a temporary immunity. Vaccination gives some degree of immunity, but the only certain protection lies in the use of sanitary precautions, and chlorination of the water.

This disease occurs in the Philippines, and in India and other parts of Asia.

The sickness known as winter cholera is not really cholera, but a fairly mild diarrheal disease. Its cause is not known, but it is probably waterborne. Although it usually occurs in epidemic outbreaks, it is actually non-infectious.

Dysentery

Bacillary dysentery is an infectious intestinal disease that occurs under the same unsanitary conditions that cause typhoid fever. The bacteria can be destroyed by standard field chlorination methods. The organism has great resistance to cold, and will live for days in soil or on clothing.

The incubation period is usually 2 or 3 days. Symptoms include frequent bloody, mucous-filled bowel movements. This disease occurs in tropical and subtropical areas.

Amoebic dysentery is an infectious intestinal disease that resembles bacillary dysentery in its symptoms; however, it is caused by a very small form of animal life, rather than by bacteria. This animal life resists ordinary chlorination, and can live in water for several days or even weeks.

The disease is carried by amoebic cysts which form in the intestines of an infected person, and are discharged in bowel movements. Drying the cyst forms will destroy them; or they can be removed from the water by diatomite filtration, and then chlorinated. However, the water must be properly treated to ensure their destruction.

This form of dysentery is widespread not only in the tropics and subtropics, but also in temperate zones. The incubation period may vary from 10 days to several months.

Diarrhea

Diarrhea is a name given to several intestinal diseases that are characterized by cramps and frequent bowel movements, with watery feces. Inadequate sanitary protection of food and water can cause diarrhea. Where the disease is caused by food, it is restricted to those who consume the contaminated food; waterborne infection is likely to be widespread. Proper chlorination measures will control waterborne diarrhea.

Schistosomiasis

Schistosomiasis is caused by a small worm that may enter the body through consumption of contaminated water, or it may enter through the skin while a person is bathing or swimming in contaminated water.

This disease is found chiefly in tropical or subtropical regions, notably the Philippines, China, Japan, Africa, northern South America, and the West Indies.

Although there are three types of schistosomes, the incubation period is the same (3 to 10 weeks) for all, and the flukes have similar life cycles. The chief variations occur according to what part of the body has been infected.

The urine and the feces of an infected person contain the eggs of this parasite. In fresh water, these eggs hatch into very small, free-swimming larvae which are not infectious to humans. However, if these larvae find fresh-water snails into which they can enter, they develop into the next form cercariae, and become highly infectious to human beings.

In water, larvae can live for only 24 hours, and cercariae for only 36 hours. The effective remedy, therefore, is to kill all snails at the water source.

Water highly contaminated with schistosomes can be detected by its milky turbid appearance. It is possible to treat small pools to kill cercariae, but they cannot be controlled in streams. Cercariae can penetrate any type of sand filters, even when they are operated at half their rated capacity. They cannot, however, penetrate diatomite filters or pad-type filters using a paper pad as filter agent.

Regular drainage, with plenty of sunlight and heat, is one of the most effective means of controlling this pest. Freshly slaked lime, in concentrations of 500 ppm (parts per million), is effective in killing the snails, as is copper sulfate in a 20-ppm solution. A chlorine residual of 1 ppm for 30 minutes is ample to remove all infection, and chloramines appear to be equally effective. Iodine in the same proportions is said to be efficient as is halazone in 4-1/2-ppm proportions.

Nonspecific Disorders

In addition to these specific waterborne diseases, there are several nonspecific disorders that are caused by impure water. One example is the staining or discoloring of teeth due to the presence of fluorides in drinking water. As little as 0.8 ppm of fluoride in water has been found to cause this staining, which is also known as mottled enamel. The teeth become brown, yellow, opaque white, or black. As the fluoride in the water is increased, the spotting of the enamel becomes more pronounced.

WATER RECONNAISSANCE

Locating a satisfactory source of water supply is an extremely important mission, and one to which the Utilities Man may be assigned. You should make use of all the data available at your headquarters, to ensure that there will be water resources in sufficient quantity, of a quality that can be speedily purified for safe use, and in locations that are accessible to vehicles as well as to personnel.

Sources of data helpful in relation to water resources are:

1. GEOLOGIC DATA AND MAPS: especially valuable as guides in locating ground water.
2. MAPS AND SUMMARIES OF CLIMATIC DATA: this type of information, which is a guide to the amount of water that may be expected in the specific area, is available for most regions of the world.
3. MEDICAL SURVEYS: the Department of the Army has published a number of technical bulletins, prepared by its Medical Department, and providing valuable data

on the water supply systems, and the waterborne diseases, prevailing in various parts of the world.

4. INTELLIGENCE SURVEYS: general information on water supply in specific areas of military operation is given in field monographs published by the Office of Naval Intelligence. A series of reports on water resources data has been issued by the Bureau of Yards and Docks. Another source of data is the series of Terrain Intelligence Folios prepared by the Intelligence Branch of the Army Engineer Corps, in cooperation with the U. S. Geological Survey; these Folios include maps, and tables of water information.

5. FIELD REPORTS: these summaries of the latest observations made in specific areas include reconnaissance reports, tactical data, prisoner-of-war interrogations, interviews with natives, and similar records and reports.

6. MAP STUDIES: all available maps and aerial photographs of the area should be studied, for indications of sources of water supply, sources of pollution and contamination, and existence of communication facilities.

Although these suggested sources, if available, should be carefully studied as a part of preliminary planning, the only positive way of selecting a water source is by actual ground observation. If you are part of a ground reconnaissance, you should make careful notes, and if possible key a sketch of a specific location to a map. This is the type of information that will prove most helpful to the person who must select the water sites on the basis of the data that you furnish.

Quantity

Satisfactory quantity will probably represent a compromise between what would be an abundant supply and what would be the minimum amount possible for the specific installation or operation.

CONTINENTAL per capita requirements (as at shore stations) depend upon climate and living standards, and upon the amount of water that will be needed for industrial operations. At established bases where adequate bathing and laundry facilities exist, a supply of 100 gpcd (gallons per capita per day) can be considered typical for personnel needs. To this amount must be added the

quantities required for water-consuming industries, or for supplying the fleet.

Reserves of water must be stored to ensure that fluctuations in demand are provided for, and that there will be water available for fire fighting, should the need arise. Since distribution systems usually provide for peak quantities, and since peaks may exceed average requirements by several hundred percent, a more uniform and economical operation of pumps and treatment is possible when surplus water is stored.

In the FIELD, it is usually necessary to place restrictions on the use of water, but under the most adverse conditions, 2 gpcd should be considered the safe minimum. Even this minimum may be impossible to provide; the absolute minimum, however, must not fall below 1 gpcd, with 2-1/2 quarts of this allowed for cooking and for drinking at meals, and the remaining 1-1/2 quarts for drinking between meals. These limited amounts may serve for short periods, but cannot be considered adequate for more than a very few days.

An adequate water supply is more difficult to obtain at ADVANCED BASES than at continental stations. Even where there is an extensive supply of surface water, there may be great obstacles to its purification for use. For example, in some Arctic and Aleutian areas, thawing and melting snow, and silting, has rendered otherwise excellent water sources unsuitable. The turbidity of these waters has become so great that it will not respond to normal treating processes.

At newly established bases, at semipermanent camps, and under actual combat conditions, per capita allowance may have to be cut rigorously. This means that such potable water as is available may be used only for drinking and cooking, with little or no provision possible for laundry and bathing.

Animals and vehicles also require water. For all draft animals, 3 gallons per day is the absolute minimum. Normal operation of a car, truck, or other water-cooled engine requires 0.1 gallon per day; in desert areas, this amount must be raised to 0.5 gallon.

For determining the quantity of water flowing in streams, you should know the cross-sectional area of the stream, and the average velocity.

Cross-sectional area may be computed from the formula,

$$A = 1/2\ (a + b)\ h$$

where

a represents width of the stream at water level (in ft)
b represents the width of the stream bed (in ft)
h represents average depth of the water (in ft)

A crude but practical method of measuring velocity is to drop a twig on the surface of the stream, and time it over a few feet of travel. Multiply the rate of travel (number of feet per minute) by 3/4, and use this product as velocity (V). Cross-sectional area times velocity gives the number of cu ft per minute of the water flow. Multiply this product (A times V) by the factor 7.5, and you have flow per minute, in gallons. This method may also be used to measure the flow from springs.

It is not possible to compute the quantity of water available in an underground water table, but when you have driven or drilled a well to tap such a source, it is possible (indeed, advisable) to measure the flow from the well. Set your pump first at a known rate of speed in gallons per minute; then keep increasing the rate of speed until the water surface in the well has stopped falling. If the pump were started at 15 gpm, and you had increased speed to 20 gpm before the water surface stopped dropping, you would record the discharge flow as 20 gpm. The distance that the water surface in the well has been lowered (the drawdown, as it is called) should also be recorded.

Quality

The need for water is such a demanding one, especially at times of intense activity and nervous strain, that men will drink contaminated water rather than endure thirst. A supply of safe water is imperative, therefore, not only for comfort and efficiency, but also in the interests of preserving the men from waterborne diseases.

Methods of determining sanitary defects in a potable water supply are discussed in the following chapter, as part of the general subject of water treatment. It is

enough at present to say that any supply of drinking water must be free of any harmful amount of BACTERIOLOGICAL contamination, and must possess satisfactory PHYSICAL and CHEMICAL characteristics.

During military operations or emergencies, a hasty estimate of quality may be all that can be accomplished. Of the possible sources, therefore, select the one that meets the following three requirements:

1. Freedom from contamination by sewage or other wastes, and freedom from enemy-distributed chemical agents or bacteria.

2. Freedom from turbidity, excessive color, and objectionable taste.

3. Freedom from excessive amounts of organic and mineral substances.

Drainage and Other Site Factors

Surface water seepage and contamination can be minimized by locating wells on sites that are provided with good drainage features. Isolated high points or hills immediately suggest themselves, but this advantage is usually offset by the necessity for deeper drilling. As in so many other situations, a compromise must be made between the ideal site, and the manpower and time that would be required to provide it.

In any event, upland sites for shallow wells should be at least 250 yards from high bluffs or deep valleys, because water usually percolates more rapidly from the formations exposed in nearby outcrops.

Where no surface or spring water is found, the search for water becomes a matter of studying the rock structure and the topography of the area. Actually, this involves a type of geologic survey, but it will be of great help to know beforehand what type of rock is most likely to be water-bearing, and what type of topography is most likely to be a clue to the presence of ground water.

The common types of water-bearing rocks are: sandstones, gravels and sands, porous basalts, fractured and cavernous limestones, and highly fractured formations of any type.

Topography that shows outcroppings of rock is encouraging. The outcrops may be at cliffs, steep slopes,

hilltops, banks of streams, shore lines, road cuts and similar excavations. Study the outcrop, and sketch it in cross section, with notes on significant features. These notes should comprise, as far as possible, the following information:

1. Type of rock
2. Thickness of stratification
3. Dip of all visible beds
4. Porosity
5. Grain size, and degree of sorting
6. Contact between formations
7. Possible breaks in the rock sequence
8. Degree of cementation of layers
9. Amount of open space, and arrangement
10. Possible cavernous conditions

Trace all outcrops as far as possible, and if you encounter seepage or zones of moisture, study and trace these, also. Rock formations that show seepage will probably yield water at other places.

After outcrops have been studied, the surface extent of the formation must be studied; this will not be a simple matter, but the information is necessary in order to determine the sites where wells should be drilled. Here, again, you must make a careful study of the type of rock, the stratification, and also the topography and the plant life.

TYPE OF ROCK may be igneous, sedimentary, or metamorphic. The igneous rocks have been formed by the cooling and solidification of molten material far below the earth's surface. In time, they may outcrop; but they are poor water carriers, since they have practically no porosity. They may, however, have fractures; and some of them (in lava flow formations) have bubble holes, tunnels, and cracks formed during the cooling process.

Sedimentary rocks are the result of layers of rock fragments, plant and animal remains, and so forth, laid down by wind or water. In the course of time, these layers have been compacted and cemented to form rocks. Gravel, sand, and clays occur in these sedimentary rock formations. It is in these layers that the best sources of ground water occur; the open spaces between adjacent grains are small (a fraction of an inch), but usually allow the water to move freely.

Metamorphic rocks have been formed by the action of heat and pressure on either igneous or sedimentary rocks. These rocks occur chiefly as slate, quartzite, marble, schist, and gneiss. They have a low porosity, but they may yield water in their joints and caverns.

STRATIFICATION or sequence can be used to identify water-bearing formations. The sequence found at the outcrop can be expected elsewhere, and if a conspicuous bed is located on a slope, the adjacent beds can be located, even though they do not crop out at the land surface. Sandstone, shale, or limestone at an outcrop indicates water-bearing beds.

TOPOGRAPHY will have typical forms throughout a specific area. A resistant limestone, for example, will appear in ledges or benches along the sides of a valley, but softer beds above or below will show gentle slopes. These variations are caused by different degrees of hardness and resistance to weathering.

PLANT LIFE is typical throughout an area of specific rock formation. Vegetation and soils, therefore, offer a good guide to the type of underlying rock. Sandstones have sandy soils, which may support forest growth. Limestones have clay soil, gray or dark. Some metamorphic rocks have soils rich in mica. Any area that has an abundance of ground water plants is worth further investigation; but if there are no ground water plants, the water table, if existent at all, must lie 60 or more feet below the land surface.

Some plants furnish not only an indication of the presence of ground water, but also a hint as to its quality. Thus, in humid regions, berry bushes, shrubs, and trees indicate good water. In deserts, reeds, sedges, and rushes indicate good quality water; pickleweeds and tamarisk indicate highly mineralized water; and palm trees and greasewood may occur where the water is of good quality, or where it is highly mineralized.

Reconnaissance Report

The report on a reconnaissance study must be clear; it must be concise, and at the same time complete. If water is available, these are the factors that must be known, in order to acquire a water supply as quickly and efficiently as possible:

1. Quantity of water available
2. Quality of water
3. Topography and rock formation
4. Climate, vegetation, and drainage
5. Test drillings
6. Site conditions
7. Estimates of manpower, equipment, and materials required

If water in the form of springs or wells was discovered in the water reconnaissance, your report will have to show definite location of these water sources, and indicate what results were obtained from tests of quality. Tests should be on turbidity, color, taste, and odor. Record the condition of vegetation around the water source, and the possible sources of pollution.

To indicate as far as possible what amount of water may be expected, describe all wells as to type, kind of casing, total depth, depth at which water was found, depth of water in well, static level of water, and drawdown of water when pumped.

Remember that finding the supply, and devising a method of distribution, is only a part of the picture of water supply. Most water is not sufficiently pure at its source to be fit for human consumption, and some type of purification process is necessary. *Utilities Man 3 and 2*, NavPers 10656-C, contains a description of the various processes—coagulation, sedimentation, filtration, and chlorination—employed to make water supplies safe. The tests that determine quality are also described. Some of this subject matter will be briefly discussed in the succeeding chapter, but before studying this next chapter, it would be a good idea to review the information given in the training course for the service ratings.

DEVELOPMENT OF WATER POINTS

In the development of a selected water point, the first step is to place the purification equipment. With this installed, it will be possible to immediately produce a certain amount of water for personnel use.

After the water point has been established, you will probably want to improve the setup, so as to produce more and better water. This may involve erection of an

extra storage tank, and arranging for the use of activated carbon. It will certainly involve the provision of facilities for distributing the water, and clearing of space for turnarounds for vehicles.

Drainage conditions will be an important factor. Remember that wherever water is distributed, there is likely to be spillage; and unless this excess water is drained away, the area will become muddy, adding to traffic difficulties.

Inspections should be made frequently, to make sure that conditions are up to standard; and if the installation is to be permanent, or semipermanent, certain records should be kept. The information recorded will help to keep things running smoothly, and enable the water point operator to know at all times what the actual water supply situation is.

These records need not be elaborate; in fact, they should be kept to a minimum. In practically all cases, it will be sufficient to keep track of three factors: daily production, daily distribution, and chlorine residual.

The daily production record will show how much water is put out each day at each water point. The daily distribution record will show how much water is delivered to each unit using the water point. The chlorine residual record should record the time when a water sample is taken, and the chlorine residual reading for each sample. With this data, you will always know how much water is being made available, who is getting it, and whether or not it is up to standards for safe use.

QUIZ

1. What are the 3 chief factors controlling water supply in a given area?
2. What are the 3 usual ways in which surface waters occur in a region?
3. The natural storage of ground water in a specific area is dependent chiefly upon the
    (a) amount of precipitation
    (b) frequency with which storms occur
    (c) plant cover sustained by top soil
    (d) composition and relative position of underlying strata

4. What are the 2 chief factors in the stabilization of the water table for a particular locality?
5. The level of the water table in a given locality is
   (a) always a flat and even surface
   (b) always coincident with surface topography
   (c) dependent upon the configuration of the area in which it accumulates
   (d) dependent upon the soil layer overlying it
6. How is the heavy rainfall of tropical regions often collected for use as a water supply?
7. The term "aquifer" is used to denote
   (a) an overland pipe for conveying water
   (b) an underlying stratum containing ground water
   (c) a spring formed by the outcropping of an impervious stratum
   (d) A reservoir of ground water forming a false water table
8. What 2 factors are involved in the formation of an artesian spring?
9. A limited quantity of ground water held in a cavity above the level of the water table established for that area is known as
   (a) an aquifer
   (b) an artesian supply
   (c) a perched supply
   (d) a ranney
10. Name the 3 usual types of spring
11. The type of spring most likely to supply a constant yield is the
    (a) artesian
    (b) hillside
    (c) outcrop
    (d) overflow
12. Most modern wells are the type known as
    (a) drilled
    (b) dug
    (c) radial
    (d) ranney
13. Upon what does the success of a dug well chiefly depend?
14. What is the purpose served by the slots in the screens placed over aquifers tapped by a drilled well?
15. The type of construction in which horizontal tunnels or wells are driven from a shallow, open well into a water-bearing stratum is known as
    (a) an artesian well
    (b) a drilled well
    (c) an open end well
    (d) a ranney well

16. Fresh water percolating to underlying strata of small islands is usually prevented from mixing with salt water at sea level zone by
    (a) the lens-like formation that commonly occurs on island coasts
    (b) the difference in specific gravity between salt water and fresh water
    (c) pumping facilities installed to raise the water to ground level
    (d) piping properly installed in the catch basin
17. What are the 3 chief causes for pollution of surface water supplies by waterborne diseases?
18. Typhoid bacteria can be readily destroyed in drinking water by
    (a) freezing the water for a short period
    (b) drying the bacilli forms, and filtering them out
    (c) applying field chlorination methods
    (d) killing fresh water snails, which serve as hosts to the bacteria
19. The waterborne disease caused by a small worm that may enter the body through the skin, or by way of water consumption is
    (a) amoebic dysentery
    (b) paratyphoid
    (c) schistosomiasis
    (d) winter cholera
20. What mineral, when present to even a small degree in drinking water, can cause the enamel of the teeth to become mottled?
21. In making a water reconnaissance for a specific area, why would you consult summaries of climatic data?
22. For field operations, what is the minimum per capita quantity that can be safely allowed, even under the most adverse conditions?
23. What is a simple method for computing water flow in a surface stream?
24. Why are igneous rocks poor water carriers, in general?
25. In developing a selected water point, the first important step is to
    (a) measure the daily production
    (b) erect the purification equipment
    (c) arrange storage tank facilities
    (d) provide facilities for distribution
26. Why are drainage conditions especially important at a water point?
27. What are the 3 essential factors for records kept at a permanent or semipermanent water point?

CHAPTER 8

WATER TREATMENT

At off-continent bases, water supply will probably be derived directly from the three possible sources: surface water, ground water, and sea water. Ground water, as you have already learned, is oftentimes relatively free from contamination, but for safety's sake should be given some treatment. If it is turbid, or brackish, purification is absolutely necessary. Surface water will almost certainly require treatment before it may be safely used. Sea water will be used only as a last resort, and will have to be distilled in order to provide a salt-free water supply.

As soon as a temporary or semipermanent camp is established, every effort should be made to utilize any supply of fresh surface water that can be brought in by pipeline, even from a considerable distance. However, the length of time that the camp will remain in location, and the number of personnel to be accommodated, will have to be weighed against the time and cost involved in providing and maintaining a distribution system from a remote source.

If fresh surface water is not available, the possibilities of ground water sources must be explored. Reconnaissance data will indicate if and where there is a fair probability of an adequate ground water supply.

When sea water is the sole available source of supply, distillation units must be employed. This type of equipment involves the use of critical materials, and requires considerable shipping space, so that its cost

per gallon of usable water produced is high. The high fuel consumption, and the cost of maintenance, also serve to make these units expensive; but there will be occasions when they offer the most practical method of furnishing water for a temporary installation. Their use should not be continued beyond the period necessary for arranging for supplies of fresh water; even with the high cost of a fresh water distribution system (supplies, pumping, and line maintenance), the cost will probably be less than that of a prolonged use of distillation units.

PURIFICATION PROCESSES

Relatively little water is sufficiently pure at its source to be immediately fit for safe consumption. Some type of treatment is required, to ensure that the water supply does not become the source of epidemic disease. Centuries ago, men learned that to evade plague and epidemics, foul water could be purified by processes such as boiling it, filtering it through charcoal or exposing it to sunlight.

The simplest method of protecting against bacteria is to boil the water. However, while no disease-causing bacteria can withstand the effects of boiling, organic matter may remain after the disease germs have been destroyed. If enough dissolved organic matter remains, the water will not be potable, and further treatment will be necessary to render it fit for use.

In the training course, *Utilities Man 3 and 2,* NavPers 10656-C, you have been told how to employ the various purification processes: sedimentation, coagulation, filtration, and chlorination. You also have learned something about the tests that are employed to ensure that water is of acceptable odor, taste, and color, and not too turbid for safe use. It is not the purpose of this training course to repeat what you have already learned in the service ratings, but it may be helpful to rapidly sum up the various processes and the physical tests.

Remember, the more you know about the reasons for applying the treatment processes and tests, the better will be the results that you obtain in discharging your duties in connection with water supply and distribution. If you have access to NavPers 10656-C, it will be advisable for you to read the text over, as a preparation for your study of this chapter.

Purification, hypochlorination, or distillation, if done properly, can make almost any water supply safe to drink. The first and most important step is to select the treatment according to the type and quality of the water. The different purification processes, therefore, are discussed here as processes only, and you must be guided by existing conditions in the methods that you will use to ensure safe water supply.

Emergency Treatment

Emergency disinfection of water in canteens is accomplished by the use of iodine tablets. Halozone tablets have been found to be less effective than iodine in destroying amoebic cysts and schistosome cercariae. Therefore, if iodine tablets are available, their use (in preference to halozone tablets) is strongly recommended.

Lyster bags, and the purification units containing diatomaceous earth filters, have been described in *Utilities Man 3 and 2,* NavPers 10656-C. The Lyster bag is primarily a dispensing unit, and the water is ordinarily distilled or purified before it is put into the Lyster bag. However, if untreated water must be used, the chemical kit which accompanies each Lyster bag will serve to purify enough water for emergency use by 99 men. The 25 gpm kit-type purification unit is capable of purifying turbid water rapidly enough to fill the canteens of a platoon inside of an hour; with extra filter pads, this unit can meet the drinking water requirements of a platoon for three days.

Chlorination or hypochlorination will successfully remove biological contamination, but there is the possibility of chemical or radiological contamination. The medical officer must take samples, and make tests of the water, whenever there is reason to suspect the presence of contaminations introduced by enemy action.

Chemical agents known as G-agent poisons can be effectively treated by the application of 1 lb of soda ash per 1,000 gal of water; this should be followed by coagulation with alum, settling, filtration, and chlorination. Activated carbon will also serve, but it must be used in extravagant quantities to prove effective.

Blistering agents (vesicants) such as Lewisite, Levenstein mustard, and nitrogen mustard, can be removed by the application of activated carbon. After treatment, the water should be tested to make sure that all chemical agents have been removed, before chlorine is added.

Treatment to remove radiological contamination is still in the experimentation stage. Time, however, is a big factor in the removal of radioactive matter, since many of the radioisotopes have a short half-life. Coagulation, sedimentation, and filtration will remove the greater part of the radioactive matter, but it is advisable to hold the use of the contaminated water to a minimum for at least a month after an atomic blast.

Sedimentation

This process of purification is satisfactory only for waters that are relatively pure, but nevertheless contain an undesirable amount of suspended matter. It succeeds only in clearing water of nonliving suspended solids. However, sedimentation is a very useful process for lightening the load on subsequent purification processes. A sedimentation basin used in connection with coagulation, filtration, and chlorination is often an economy measure, since it reduces the amount of chemical needed in subsequent treatment.

To allow settling particles time enough to reach the bottom of the basin, the velocity of flow through the basin should be retarded. The higher the velocity, the more chance that solid matter will be carried through the outlet before it can sink to the bottom. No basin should provide for a velocity of more than 1 fpm, and a rate of 1/10 fpm would be preferable.

Velocity is measured by dividing the volumetric rate of flow through the basin by the vertical cross-section area of the basin. The length of flow, or "period of retention," is computed by dividing the volume of the basin by the volumetric rate of flow. Inasmuch as the greater part of solid matter settles during the first few hours, the retention period should be counted in hours; in basins where sludge is removed by mechanical devices, the retention period may be as short as 3 hours. However, a 6-hour retention period is recommended whenever the time factor will permit.

It is important to avoid introducing currents into a sedimentation basin. For this reason, a long, narrow basin is best, since cross currents may develop in a wide basin. If the water entering the basin is considerably colder than that already there, bottom currents may be developed. The result will be a disturbance of the sludge along the bottom, forcing the solids upward into the water. The reverse situation, in which the entering water is warmer than that in the basin, is less undesirable, since the sludge is not disturbed.

Inlet and outlet devices can be installed to prevent currents or surging in the basin. Low baffles, which form protected pockets in which the sludge can collect, are good devices for reducing the effect of bottom currents. Weirs, overflow troughs, or manifolds with two or more outlets into the discharge channel, will minimize the effect of surging, but are not particularly effective in controlling currents.

Covers on sedimentation basins can provide favorable conditions for fungus growth or the breeding of insect eggs. If covers must be used, to avoid difficulties from wind and ice, make sure that there is sufficient provision for ingress and egress of air.

Coagulation

Certain chemicals, when added to water, will form a jelly-like precipitate. This substance itself is insoluble, and by its weight gradually descends to the bottom of basin or container. During its descent, the precipitate adsorbs (that is, causes to adhere to its surface) other suspended matter; thus it hastens the process of sedimentation. In occasional cases, coagulation, sedimentation, and chlorination are sufficient treatment for a water supply, but in most cases they are only a preliminary step in the preparation for filtration.

The FORMATION OF THE FLOC consists of the following steps:

1. Addition of a chemical which reacts with the alkaline constituents of the water to form the gelatinous precipitate (floc) which will entrap particles of suspended matter.

2. Rapid mixing for a period of 1 to 5 minutes, to distribute the coagulant through the water.

3. Slow mixing for about 20 to 30 minutes, to permit the floc to grow, and to carry along suspended material and bacteria.

After flocculation has been accomplished, the water is passed through a large sedimentation tank, where the floc settles out. In continuous-flow tanks, the detention period should never be less than 1-1/2 hours. Sedimentation without coagulation requires a much longer settling period.

TEMPERATURE is an important factor in coagulation, since floc will form with less chemical at high temperatures than at low ones.

ALKALINITY OR ACIDITY of the water that is being treated is another important factor in coagulation. Floc formation is closely associated with the H-ion concentration, and this concentration is a measure of the intensity of acidity or alkalinity.

This might be a good time to explain the H-ion concentration, and its relation to the pH value, a term which you will encounter in any discussion of coagulation, or of testing for residual chlorine.

The amount of H-ion concentration provides data on the corrosive character of a sample of water. It is expressed as the weight of hydrogen in ionic form in a 1,000-milliliter sample. From a mathematical formula expressing the relationship between a solution in which H-ions equal one and a solution with any other H-ion concentration, a *p*H value (which in the formula is the logarithm of the reciprocal of the H-ion concentration) is developed. A *p*H value between 4.5 and 7.5 is optimum, depending upon the impurities present. In general, water becomes increasingly corrosive as *p*H value drops.

OTHER CHARACTERISTICS AND CONDITIONS of water that will affect its coagulation are: color, turbidity, and hardness. The proper amount of coagulation, period of coagulation, and other operating conditions, therefore, cannot be specifically stated, but must be learned through experience.

When alum is used for coagulating water, it tends to lower the *p*H value, and it may become necessary to add lime or soda ash in order to prevent the water from

becoming unduly corrosive. This is an important fact to keep in mind if the water system involves the use of metal containers for storage, or metal pipe for distribution.

Filtration

Water containing suspended matter may be strained through cloth, charcoal, diatomaceous earth, or a similar porous medium, to clarify the water for safe use.

The 25 gpm purification unit described in *Utilities Man 3 and 2* is equipped with a filter of powder-like diatomaceous earth. This matter, often called diatomite, consists of the skeletal remains of minute algae. It is inert to water, and to water-treatment chemicals.

A DIATOMITE FILTER requires a rigid supporting base, yet one that is porous enough to permit maximum flow, without significant loss of head.

Figure 8-1 illustrates the proper arrangement of a diatomite filter unit. Operating and maintenance procedures, including precoating and backwashing, are described in NavPers 10656-C.

A common method of filtration is to pass the water, by gravity, through a layer of FILTER SAND. This provides for mechanical straining of the suspended matter that is too large to pass between the grains of sand; the smaller particles of suspended matter, and bacteria, settle upon the sand grains by adsorption. The greater the amount of suspended matter and bacteria that adheres to the sand, the better the adsorption—and consequently the filtration—will be.

You will sometimes hear this suspended matter referred to as "colloidal matter." Colloids are gelatinous substances that are seemingly soluble in liquid, but that are actually in a state of very fine dispersion.

Figure 8-2 shows the construction of a gravity sand filter. If local material and manpower are available, these filters are especially advantageous, since they require a minimum of mechanical equipment.

Sand filters may be of the slow-sand or rapid-sand type. The slow-sand filters have little military value, because of their high cost per unit of capacity, and the large filter areas required. However, if native labor and materials are available, slow-sand filters may be

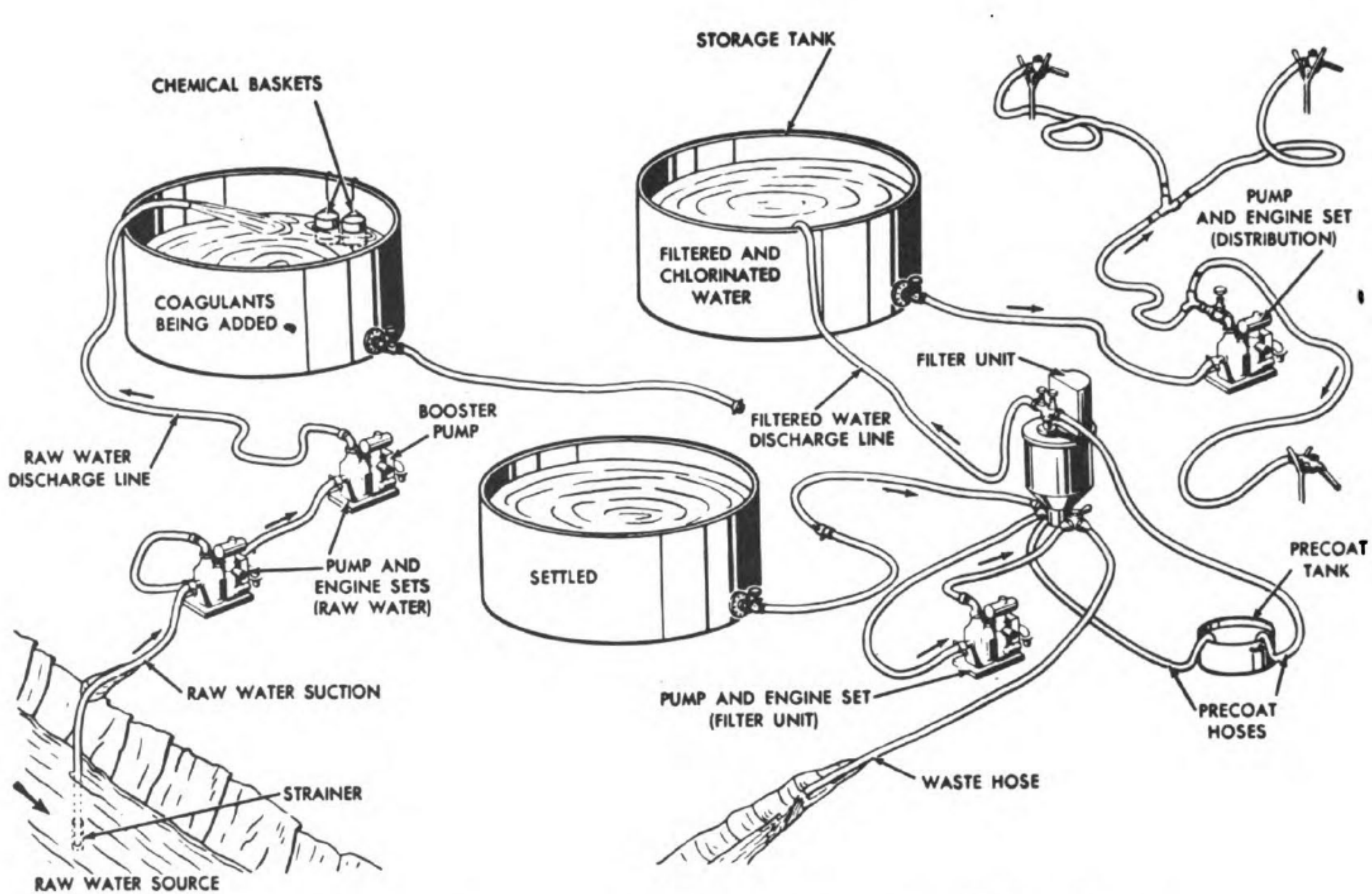


Figure 8-1.—Typical arrangement of diatomite water-purification equipment.

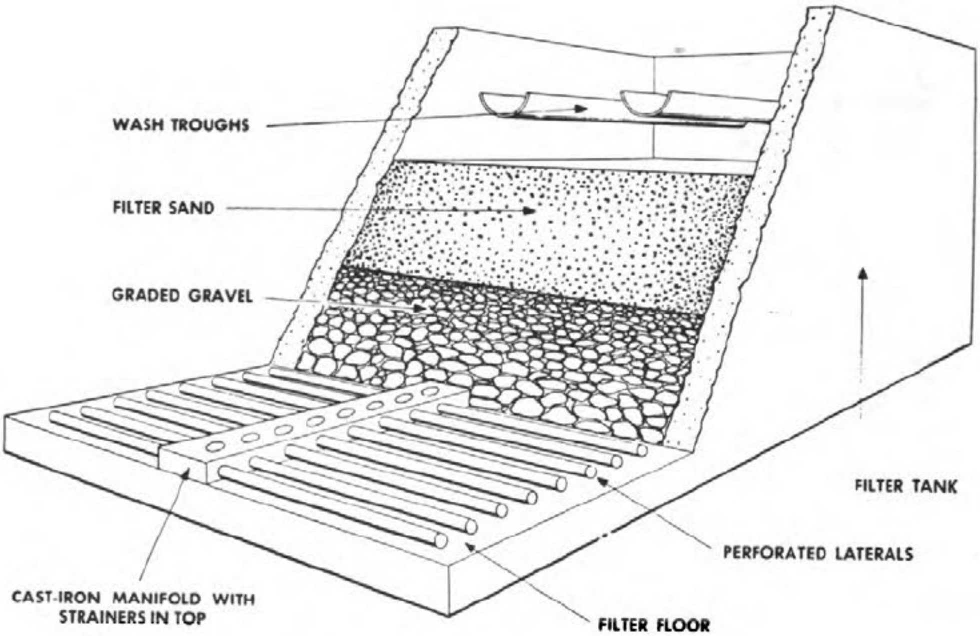


Figure 8-2.—Cutaway view of a gravity sand filter.

constructed for permanent or semipermanent installations where the water supply is contaminated with amoebic cysts, and where it is difficult to obtain diatomite filters.

A number of processes combine in the rapid sand filters to remove impurities. Straining is most effective in the upper few inches of the sand. Carryover of floc from coagulation and inorganic matter which has not settled improves the straining action by forming a mat of fine material on the surface. When sufficient organic matter is present, micro-organisms grow in the mat and further improve the straining. When the water to be filtered is relatively clean, or has been suitably prepared by coagulation and sedimentation, the biological activity by micro-organisms is less important.

The most important aspect of filtration is its contribution in lowering the bacteria count of water, and thus contributing to the health of those who use the water. A slow sand filter (that is, one in which the water is filtered through the sand layer at a relatively low rate) will remove from 98 to 99 percent of the bacteria in the raw water. A rapid sand filter will be somewhat less efficient in lowering bacteria count.

Variations in the rate at which a filter is operated can cause disturbance of the colloidal contents; therefore, a steady rate of operation, whether slow or rapid, will produce the best results. Depth of sand tends to steady the action, and for this reason sand filters in municipal systems are often made from 24 to 30 inches deep. Actually, these depths are not necessary, since the filtering action will seldom penetrate to a depth of more than 6 inches.

Rapid sand filters should be backwashed when they become so clogged that the filtration rate begins to fall off, or when the filtered water begins to show an increase in turbidity. The normal period between washes is 24 to 48 hours. If filters are allowed to operate too long without washing, or if the washing process is incomplete, filter difficulties are almost certain to develop. The first evidence of trouble will be the appearance of small mud balls on the surface of the sand. These grow in size until they penetrate the bed during washing and form internal accumulations of mud. A condition is soon reached which requires complete removal of sand and gravel for cleaning and recharging.

There are several sanitary precautions that are important in filter plant design and operation. They include:

1. No cross connection or interconnection should be permitted to exist in a filtration plant between any conduit carrying filtered or postchlorinated water and another conduit carrying raw water or water in any prior stage of treatment.

2. No conduit or basin containing purified water should be permitted to have a common division wall with another conduit or basin containing raw water or water in any prior stage of treatment.

3. No conduit carrying raw water, water in a prior stage of treatment, or drainage from laboratories, toilets, floors, or roofs, should be located in or pass through any conduit or tank containing finished water.

4. All filter plant drains should be designed to prevent surcharging by flood waters or by drainage water discharged during emptying of tanks and washing of filters. The main filter wash water drain, the clear well drains, and the ground water drain around or beneath the clear

well should each be separate and have a separate outlet which receives special attention with regard to protection from flooding. In no case should these drains be connected to a public storm or sanitary sewerage system.

5. Toilet and laboratory wastes originating within the filter plant should be discharged through a separate sanitary system so located and designed that there is no possibility of leakage or flooding of these wastes into the water under treatment.

6. Where possible, filter plants should be located on high ground above and distant from public sewers and should be surrounded by well parked and policed areas.

The provision made for storage of filtered water will depend upon the permanency of the installation, the topography of the region, and other variable factors. The main precaution to be taken is against any possible recontamination of the filtered water. The reservoirs should be thoroughly tight against external leakage, should be above the ground water table, and should have no walls in common with plant units containing water in the process of treatment.

Reservoirs may be located beneath the filters. Such storage facilities are usually known as "clear wells." They should be constructed of brick or masonry, and have adequate protection against leakage.

Reservoirs constructed above the land surface may be concrete, steel, brick, or wood. Trap doors and inspection openings should be properly sealed and locked. Vents must be screened to prevent the entrance of insects or rodents.

The interior of storage units should never be waterproofed with tar or asphalt, since these materials will impart an objectionable taste to the water, and may cause undesirable chemical reaction with the materials used in the water treatment.

Where a filter building is erected, the heat losses through roof and outside walls will be high. Temperatures must be kept above freezing, or operation will become very difficult, due to the freezing of small pipes. Unit heaters might seem the logical answer, but unfortunately they cause another difficulty—condensation of water on the inner walls. By and large, the most economical and

practical method of heating these building will be to install insulation in the roofs. The expense of this insulation will be more than offset by the savings in fuel, and the avoidance of the difficulties arising from condensation.

Chlorination

Sedimentation settles those particles of solid matter that are heavier than the water in which they are suspended. As long as water is in motion, these heavy solids will remain in suspension; in still water, however, they sink to the bottom.

Coagulation is the process of adding to the water some chemical agent that gathers the suspended impurities into larger particles, so that they settle more rapidly.

Filtration removes from the water most of the remaining particles of suspended matter.

After the application of these three processes, a water supply may still be unsafe for human consumption. A further treatment by chlorination is usually necessary, in order to remove minute organisms that might cause widespread illness and even death.

The purpose of chlorination, therefore, is the disinfection of water; that is, the killing of algae, protozoa, and other micro-organisms. This purification process is not in any sense a substitute for filtration, but is universally used in water that is obtained from questionable sources. It may have no effect whatever upon the physical characteristics of the water; again, it may have a detrimental effect.

Occasionally, chlorine is used with unfiltered water, but only in those cases where the existing degree of pollution is very small, and disinfection with chlorine is all that is required for improving the water.

Just why chlorine should be so effective as a means of purifying a water supply is not too well understood. Some authorities believe that the decomposition of chlorine releases oxygen, and thus oxidizes the organic matter of the bacteria. Another explanation that has been advanced is that the chlorine forms toxic substances in its reaction with bacterial cell walls, and that it is these toxic products which kill the organisms.

The amount of chlorine to be used in a particular water supply depends upon a number of factors: organic content of the water to be treated, hydrogen-ion content, temperature, and duration of the contact. Turbidity must also be considered, since any considerable turbidity will reduce the effectiveness of chlorination. Because of the difficulty of evaluating the net result of so many factors, it is customary to judge of the desired results by measuring the residual chlorine.

If organic content of the water is low, try using about 8 lb of chloride to 1 million gallons of water. The residual chlorine (expressed as parts per million) would probably be 1 ppm, which is the military requirement for a field water supply. The test (made by adding orthotolidine to a tube containing a sample of the water) must not be made until at least 10 minutes after application of the chlorine; another 10 or 15 minutes should elapse before the water is distributed for consumption. Remember that chlorine can be dangerous if taken in concentrated doses.

A good rule is to allow 1/2 hour between the time of application of the chlorine and the time of consumption of the treated water. This ensures that there will be time enough for the chlorine to produce effective results, and to protect users against receiving overdoses of chlorine.

The APPLICATION of chlorine to the water will have the same effectiveness whether the chlorine is in the form of a powder, a liquid, or a gas. The gas is a deadly poison, and must be handled with great care. The liquid, unless maintained under pressure, reverts back to the gaseous state, and regains the characteristics of chlorine gas. The powder forms, therefore, are safest to use.

The type of chlorine generally used for emergency or small water supplies by the Navy is calcium hypochlorite, which is chlorinated lime consisting of 70 percent available chlorine by weight. This is probably the most effective of the powdered compounds. At advanced bases, it can be fed to the water supply through a hypochlorination unit.

Chlorine is used in gas or liquid form in many municipal systems; therefore it is advisable for the Utilities Man to know something of its application, and particularly

to know something of the dangers involved in handling it in its liquid or gaseous states.

As a gas, chlorine combines readily with water, but it also becomes extremely corrosive to metals, upon exposure to moisture. In color, the gas is greenish-yellow; it is 2-1/2 times heavier than air; and it has a pungent, disagreeable odor. It is extremely dangerous to breathe, and affects the membranes of the nose, throat, and lungs.

Larger systems generally use chlorine in a solution feed. Liquid chlorine in steel cylinders under pressure is vaporized, and the gas is dissolved in a minor water supply. The resultant chlorine solution is then fed to the desired point of treatment.

When chlorine solution feed equipment is used, keep the chlorinators and the lines leading to them free from dirt and gummy deposits such as those caused by oil from valve packings, and also by the use of the wrong cleaning agents. The only satisfactory cleaning materials for chlorinator equipment are methane derivatives (such as wood alcohol or carbon tetrachloride), which will not convert into solids by action with the chlorine.

Fortunately, chlorine gas gives warning of its presence, either by sight or smell, before the concentration becomes great enough to be really harmful. The following PRECAUTIONS should at once be taken:

1. Close the tank valve.
2. Avoid panic.
3. Refrain from coughing.
4. Keep mouth closed.
5. Take short, shallow breaths; avoid deep breathing.
6. Keep head as high as possible; chlorine gas, being heavier than air, seeks the lowest level.
7. Withdraw from the affected area.
8. If anyone has been overcome, remove him from the affected area, place him flat on his back, and keep him warm. Call medical personnel immediately.

Chlorine produces no cumulative effects, and recovery from mild exposures is usually complete. However, men do not become hardened by continual exposure, and the fact that you have once been overcome, and made a recovery, does not afford any immunity in case of subsequent exposure to concentrations of this gas.

Once chlorination equipment has been started, it must be kept going continuously to ensure that all water supplied is disinfected. Manual control of the equipment, including any necessary adjustment in dosage, is possible where the rate of flow in the system is relatively constant. However, if maximum and minimum flow vary as much as 50 percent from average flow, there must be some provision for automatic proportioning of the rate of chlorine feed to the rate of water flow.

Chlorinators for feeding gas, and cylinders in which chlorine is stored, must be kept at a temperature above 60 F, yet lower than maximum outside summer temperature. The best arrangement is to provide special spaces, equipped with exhaust fans that can be operated from outside the space.

Suitable gas masks and a bottle of ammonia (for testing for leaks) should be kept just outside these cylinder storage spaces. Ammonia is an excellent testing medium, because, when it mixes with chlorine, it forms a white vapor.

Replenish your stock of chlorine gas or compounds when it becomes low. Store calcium hypochlorite carefully, to avoid danger of fire.

When you start the chlorination process, you must have a sufficient number of cylinders to connect to the chlorinators, so that you can be sure of continuous adequate operating pressure.

Scales, preferably of the recording type, should be available for weighing cylinders, so that you can check the rate of feed on the chlorinators by watching the loss of weight figures for the cylinders.

Hypochlorination

For some water distribution systems, chlorination may be the only treatment required. In such cases, a hypochlorinator is used. This is automatic equipment, for the continuous injection of an amount of chlorine solution into a water line; the amount of solution varies according to the amount of water flowing through the pipe. This same type of equipment can be used on an existing water supply system that has been damaged or is in a state of disrepair, until such time as the system can be put back into satisfactory operation.

Hypochlorite solutions should be prepared in a separate mixing tank, then diluted and allowed to settle so that only clear liquid is withdrawn to the solution storage tank which supplies the chlorinator.

The strength of hypochlorite solutions should be checked frequently, and should be renewed as often as necessary to maintain them at satisfactory strength for accurate control of chlorination.

Since a Utilities Man may often be called upon to work with Army equipment, an illustration of an Army hypochlorinator is shown in figure 8-3. The unique feature of this type of equipment is that it is powered entirely by the pressure of the water that it is treating, and one man can operate it with only intermittent attention.

The principal parts of this unit are: water-pressure-operated hypochlorinator, balancing water valve, water meter, range-adjusting valve, and pressure-regulating valve.

Water that is to be chlorinated flows into the unit through the range-adjusting valve, past the hypochlorite

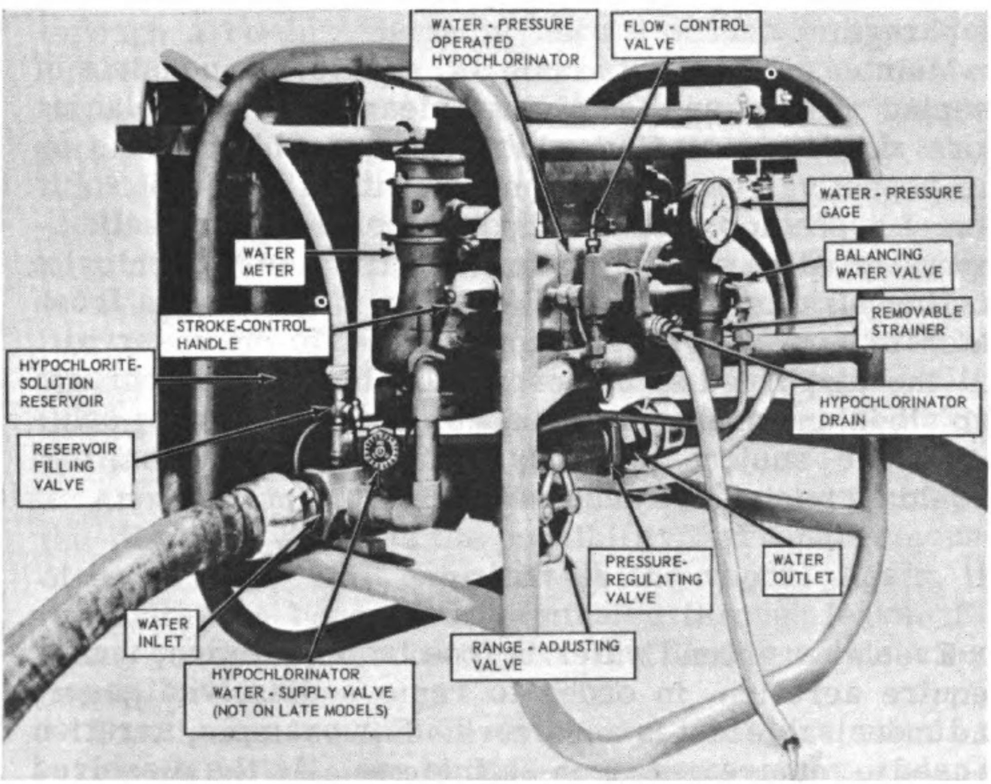


Figure 8-3.—Hypochlorinator unit.

inlet, and out through the pressure-regulating valve. A flow-control valve maintains constant flow, regardless of pressure changes at the water inlet.

The balancing water valve builds up, behind the pump diaphragm, a pressure equal to the pressure in the water line. The strainer installed below the balancing water valve should be removed and cleaned periodically.

The water meter controls the number of strokes per minutes of the hypochlorinator opening and closing the balancing water valve. The meter is actuated by water diverted through it from the main line.

The range-adjusting valve controls the speed of the water meter by regulating the flow of water from the main line through the meter. Closing this valve increases both the amount of water diverted through the meter, and the speed of the meter. Opening the valve has the opposite effect.

The pressure-regulating valve maintains the necessary pressure (10 psi) to keep the hypochlorinator unit operating. It is a spring-loaded diaphragm valve, and will not open until 10 psi pressure exists under the diaphragm.

Maintenance of this unit is simple; it consists of keeping valves and strainers clean, and of replacing worn diaphragms. The white coating which forms on the poppet valves can be removed with a 5 percent solution of hypochloric acid. The strainer under the balancing water valve should be cleaned daily; the hypochlorite suction strainer must be cleaned each time that a fresh batch of hypochlorite solution is added to the reservoir. All the diaphragms, but especially the main diaphragm (which is in constant contact with the hypochlorite solution), are subject to fairly rapid decomposition, and should be periodically inspected.

Aeration

Even when ground water is free from pollution, it may require aeration, in order to remove dissolved gases, and undesirable tastes and odors. For example, aeration is used to remove hydrogen sulfide gas. As the dissolved gas is dissipated into the atmosphere, taste and odor improve. Aeration generally saturates the water, which does

result in improvement in taste but may cause corrosion problems in the system.

Any one of the following methods of aeration may be employed:

1. Exposing the water to the atmosphere, in open basins or reservoirs.
2. Flowing the water over cascades, steps or similar arrangements.
3. Trickling the water through a perforated trap.
4. Introducting air through perforated pipes, strainers, and porous plates.
5. Spraying the water through the air, through nozzles.

The use of nozzles to spray the water through the air is probably the easiest of the suggested methods, and it is the most effective in terms of the effort involved.

DISTILLATION UNITS

Of all the methods of producing potable water, distillation is by far the safest. The water is brought to a boil, and the vapor is carried through tubes that run through a cooling medium; here it condenses again to a liquid, and is caught in a container. The animal and vegetable growths, the chemical salts, and other impurities held in suspension, remain in the container in which the liquid is boiled.

The distillate thus obtained cannot be considered absolutely pure. If the original water supply contains a volatile gas or liquid that has a boiling point lower than that of water, this gas or liquid will vaporize even before the water does, and will thus be carried along through the system, to condense with the vaporized water at the later stage.

Another factor that detracts from absolute purity of the distilled water is the possibility that small amounts of raw water will entrain with the vapor. Again, the distillate can become contaminated through leaks. For these reasons, chlorination of distilled water is a necessary precaution.

Distillation equipment is costly, and care should be taken not only to avoid its unnecessary use, but also to control as far as possible the quality of the water that is processed. For example, sending gritty water through

a unit puts a load upon the equipment that may damage the unit as well as detract from the quality of the processed water.

When sea water is the only available source of supply, or when the source becomes contaminated with salty water, distillation equipment is an absolute necessity. Every precaution should be taken to avoid any excessive wear on the equipment, so that its only function will be to recover fresh water from the salt water. Intakes should be so planned as to eliminate, as far as possible, the possibility of bringing sand, oil, or organic matter in with the water.

The preferable method of securing the water supply will be by constructing wells along the beach. These wells eliminate many of the problems caused by surf and tides, and lend themselves to overhead concealment. On rocky, coral beaches, however, offshore intakes must be used.

For offshore intakes, some type of intake screen must be installed. The screen must be positioned vertically, and it must remain off bottom at low tide and yet not ride so high in the water that it can suck air into the system. Figure 8-4 shows how an empty fuel drum, and a weight used as anchor, can be used to properly position a saltwater intake screen. The anchor secures the screen against the action of winds and waves. The hose leading to the unit can be connected to a rigid pipeline lying along the shore bottom.

As mentioned before, the chief disadvantage of this process is that distillation equipment is costly; under most circumstances, therefore, it is used only at temporary or advanced bases.

During World War II, distillation units of various capacities were used; for example, the 85 gph and 150 gph, both gasoline driven. Distillation units are now standardized at 85 gph and 200 gph units, both diesel driven. A larger unit is in process of development by the Bureau of Yards and Docks, but it will not be available until late 1958 or early 1959.

Army distillation units may be in use at some installations, so that the Utilities Man must understand their operation and maintenance also.

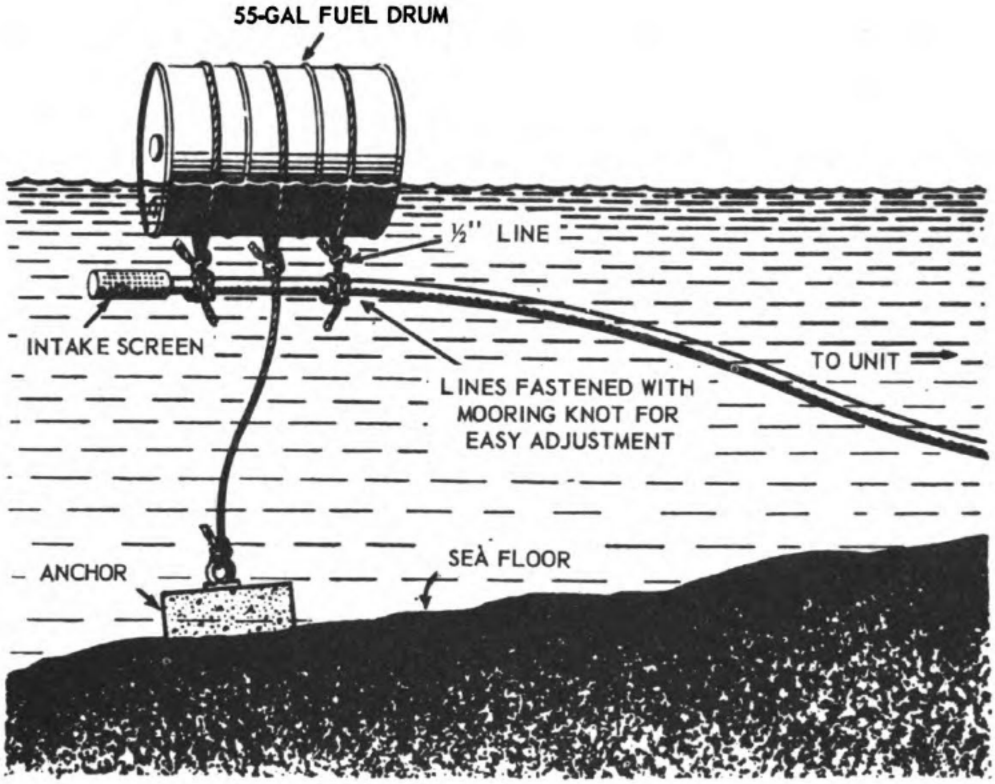


Figure 8-4.—Float type sea water intake.

Types

There are two general types of distilling plants: steam distillation and vapor compression plants.

The steam distilling plants operate from power plants or auxiliary boilers. The basic components are an evaporator and a condenser. Boiler steam is fed to the evaporator, and vaporizes the liquid. A greater amount of distillate can be obtained per lb of steam by using a multiple-effect evaporator. In this type of equipment, the heat of the vapor formed vaporizes additional liquid at lower pressures and temperatures.

Vapor compression plants use compression heat from a diesel or electric driven compressor. Heat is applied to bring the plant to operating temperature—that is, the point at which steam is first produced within the evaporator tubes. The steam produced within the evaporator at atmospheric pressure is then drawn off and compressed in the compressor. Then the steam, its temperature raised by compression, is discharged to the area around the

evaporator tubes, and its heat is transferred through the tube walls, causing the cooler liquid inside the tubes to boil, and generate more steam.

The 85 gph distillation unit is portable, skid-mounted, self-contained, and powered by a diesel engine. The 200 gph unit is similar, but has a higher capacity, as is indicated in its name. Both these units, however, will produce 1 gal of distillate for each input of 2 gal raw water. These two units replace, respectively, the 83 gph and the 150 gph units in use during World War II.

Chapter 10 of *Utilities Man 3 and 2,* NavPers 10656-C, includes a detailed discussion of the 85 and the 200 gph units. The description covers the components of these units, the flow of raw water and distillate, and the operating, maintenance, and repair procedures.

If you are at an installation where Army distillation equipment is in use, there will probably be a technical manual that you can consult, to learn how to operate the unit at rated capacity.

The Army units are either fuel-fired (oil) or compression-type plants. The 3,000-gpd Badger plant, which is likely to be the one that you operate, is a compression-type unit. The compressor draws steam from the evaporator, compresses it, and discharges it to the condenser. Actually, the evaporator and condenser are a single tube-type unit, but in three sections. At the bottom is the raw water section; the middle section is a combined evaporator and condenser; and the top or dome section contains the steam.

Water enters above the upper tube sheet of the middle section and passes to the lowest section. An overflow, or blowdown, pipe provides for the discharge of water that has not been converted to steam.

Power to operate pumps and compressor, and to furnish heat to the system, is supplied by a water-cooled gasoline engine with water-cooled manifold.

Cold Weather Operation

Freezing temperatures will have little effect on the performance of a distillation unit, if protective side panels and shields are furnished. Do not, however, use antifreeze in the water-cooled engines; the engine

cooling systems of the compression-type units are part of the distillation system, and in the multiple-effect units, the engine water will evaporate too rapidly.

Precautions

Applicable to all units:

1. Have raw water as free as possible of silt or sand, before it is fed to system.
2. Make sure that the reservoir for the raw water is of a capacity to ensure maximum settling.
3. Keep engine and burner fuel free of water and foreign material; strain, and store in closed container.
4. Keep all belting free of grease, oil, gasoline; keep sectional belting dry.
5. Keep setscrews and couplings tight; keep threaded hubs clean, and protected against corrosion.
6. Keep valves lubricated, and valve packing snug, but not tight; never force a control valve or a shutoff valve.
7. Provide piping supports to eliminate vibration; keep piping free of leaks.
8. Maintain pump shaft seals carefully; make sure that the packing follower fits squarely into the gland. Packing in the gland, however, should not be too tight.
9. Never run pumps with a closed discharge; the control valve should be cracked slightly, so that some water discharges.
10. For prolonged shutdowns, drain the unit completely.

Applicable to oil-fired units:

1. Clean fuel oil strainers and blow off safety valves once a day.
2. Keep the combustion chambers free of carbon deposits.
3. After every 10 hours or so of operation, blow down 2 or 3 gallons from each evaporator.

Applicable to compression-type units:

1. Never attempt to shorten starting period, as this will overload the engine.
2. Never run the engine above its specified starting speed.

3. Do not make adjustments in steam shaft seals unless abnormal quantities of steam are being discharged.

4. Keep all insulation grease- and water-free.

PHYSICAL TESTS ON WATER SUPPLY

The suspended or dissolved impurities in water can sometimes be seen by the naked eye; some can be detected by odor, taste, or color; some can be determined only by laboratory tests.

Table 1 indicates the more common sources of contamination in water, and the results which they have on the characteristics of the water. The suspended impurities are usually far more dangerous to health than are the dissolved impurities, and must be removed or destroyed before the water can safely be consumed by personnel.

The physical tests made on water are usually concerned with odor, taste, color, turbidity, and temperature. Then there are the tests for determining proper floc formation, the hydrogen-ion concentration, and the residual amount of chlorine after chlorination of a water supply. These latter three tests are described in chapter 8 of NavPers 10656-C.

Odor and Taste

The presence of noticeable odor and taste in a water supply may be the result of purification processes, as well as of matter dissolved by the water in its flow over the ground surface, or through underlying strata. In an established water distribution system, disagreeable odor or taste may be imparted to the water by solution of, or reaction with, coatings on the pipes and reservoirs. In general, an objectionable odor or taste can be attributed to one or more of the following conditions:

1. Micro-organisms, either dead or alive, are present in the water.

2. Oxygen is present in combination with organic matter, or there are dissolved gases such as carbon dioxide, hydrogen sulfide, or marsh gas.

3. The water contains mineral substances such as sodium chloride, iron, sulfates, or carbonates.

Table 1—Common Impurities in Water.

Suspended Impurities	Organisms			Some cause disease
Suspended Impurities	Algae			Cause, taste, odor, color turbidity
Suspended Impurities	Suspended solids			Cause murkiness or turbidity
Dissolved Impurities	Salts	Calcium and Magnesium	Bicarbonate	Causes alkalinity, hardness
Dissolved Impurities	Salts	Calcium and Magnesium	Carbonate	Causes alkalinity, hardness
Dissolved Impurities	Salts	Calcium and Magnesium	Sulfate	Causes hardness
Dissolved Impurities	Salts	Calcium and Magnesium	Chloride	Causes hardness corrosive to boilers
Dissolved Impurities	Salts	Sodium	Bicarbonate	Causes alkalinity
Dissolved Impurities	Salts	Sodium	Carbonate	Causes alkalinity
Dissolved Impurities	Salts	Sodium	Sulfate	Causes foaming in steam boilers
Dissolved Impurities	Salts	Sodium	Fluoride	Causes mottled enamel of teeth
Dissolved Impurities	Salts	Sodium	Chloride	Causes salty taste
Dissolved Impurities	Iron			Causes taste, red water, corrosive to metals
Dissolved Impurities	Manganese			Causes black or brown water
Dissolved Impurities	Vegetable Dyes			Causes color, acidity
Dissolved Impurities	Gases	Oxygen		Corrosive to metals
Dissolved Impurities	Gases	Carbon dioxide		Causes acidity, corrosive to metal
Dissolved Impurities	Gases	Hydrogen sulfide		Causes odor, acidity, corrosive to metals
Dissolved Impurities	Gases	Nitrogen		No effect

4. The water has been polluted by oil, tar, or other waste products.

When objectionable odor and taste are readily apparent to the consumer, they can cause the men to drink less than they actually require, even though the water can be consumed without causing any physical harm.

The best remedy (especially in the field) is to use aeration and treatment with activated carbon.

Activated carbon is a specially treated powdered carbon capable of adsorbing not only finely divided solids, but also liquids and dissolved gases. It must be used carefully with due attention given to the quality, dosage, mixing, and contact period. A dose of 3 ppm is generally sufficient, but an increase to 8 or 10 ppm will be necessary where taste and odor is caused by pollution from industrial waste.

Color

Color is caused by substances in solution, due to leaching from organic matter with which the water has come into contact. Again, color may be only apparent (not real), and may be the result of a combination of substances in solution and suspension. If you have filter paper for testing color, first centrifuge the water vigorously, so that only true color will be tested by the paper.

The sanitary significance of color is slight, but its presence may make personnel hesitate to drink otherwise palatable water. In some cases, color may complicate coagulation in the treatment processes.

Turbidity

Turbidity frequently indicates a surface pollution, although in other cases it may be due to the presence of fine particles of clay or sand, not especially detrimental to the potability of the water, or to its industrial use. A microscopic examination of the suspended matter, if it can be made, will be the best way of determining the cause of the turbid appearance.

After sedimentation, turbid water should meet the requirements of from 5 to 10 ppm of suspended matter. A turbidity of less than 3 ppm will not even be noticeable.

Testing is done by use of the turbidimeter, illustrated in figure 8-5. The first step is to prepare standard turbidity solutions, for use in the test. Fill two square 8-oz

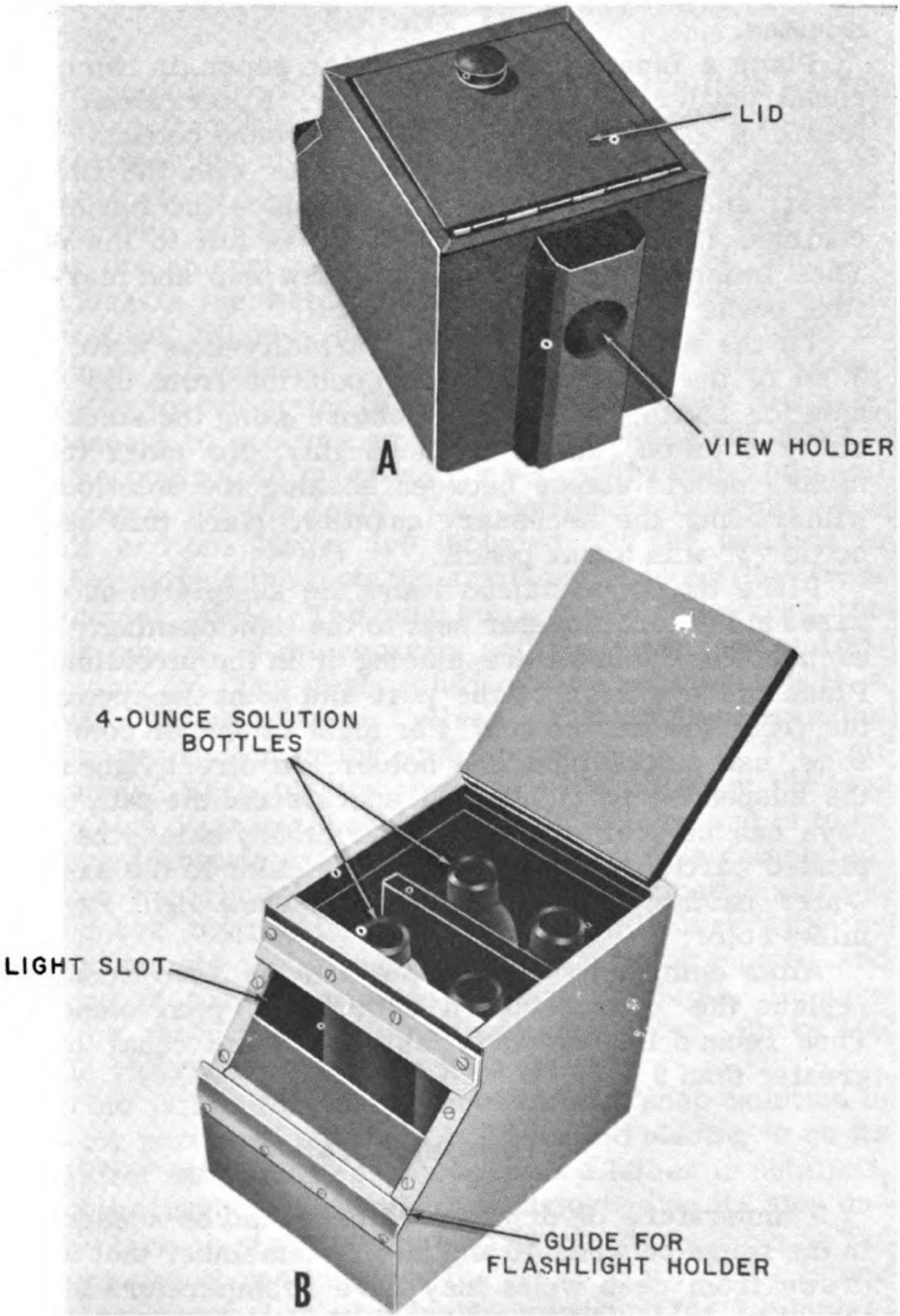


Figure 8-5.—Turbidimeter.

bottles with clear drinking water. Place small pieces of filter paper in each bottle, and shake the bottles until the paper becomes fluffy and gelatinous. Then add 1 ml (Milliliter) of alum solution to each bottle, and shake for 5 minutes.

Place a funnel, lined with filter paper, in two of the round bottles in the turbidimeter. Filter about one-fourth of each 8-oz bottle into the round bottles. Then remove the funnel, rinse the bottle with the filtered water, and discard this water. Replace the funnel and continue filtering until each bottle is full to the neck. Then immediately seal with a screw cap and mark the first bottle as "O" with a wax pencil.

To the second bottle of this turbidity-free water, add 3 ml of the standard turbidity solution from the stock solution bottle. Immediately before using the stock turbidity solution, shake it thoroughly. No more than 1 minute should elapse between shaking the solution and withdrawing the necessary quantity. Mark this second bottle "3" with a wax pencil.

Place the zero standard and the sample to be compared in the turbidimeter next to the light opening. Wipe each bottle clean before placing it in the turbidimeter. Place the eye near to the port and point the opening in the front toward the sun. For night or indoor comparisons, use a flashlight and holder. In direct light rays, the suspended particles will sparkle and the path of the rays can be plainly seen. Under cloudy skies, the suspended particles give a milky white color to the sample. Water having no turbidity will not show light rays or milky color.

After comparing the sample and the zero standard, replace the zero standard with the 3 ppm standard. Then record the turbidity as less than, equal to, or greater than 3 ppm.

Temperature

Temperature of drinking water should be somewhere in the range between 40 and 50 F. Remember that water drawn from deep wells may have a temperature higher than that drawn from shallow wells. Above 50 F, water becomes less palatable, and is certainly less well suited

to such uses as air conditioning. At temperatures above 85 F, water is unfit for human consumption.

Salinity Tests

You can make four salinity tests with the field water, quality-control kit. Each test serves to identify mineral characteristics of the water. The soap-hardness test is a measure of the total hardness, usually calcium and magnesium salts in the water. The alkalinity test indicates the amount of carbonates, bicarbonates, and hydroxides in the water. The chloride test measures the amount of chloride ions and indirectly the amount of common salt present. The fourth test, the sulfate test, is made to determine if enough sulfate, above 250 ppm, is present to produce undesirable physiological effects.

The control kit provides the necessary materials and equipment for the tests. Two bottles of reagents, one small and one large, are included. As the solution is used up during the test, the small bottle is refilled from the larger bottle. The test bottles have two marks, the lower one at 50-ml capacity and the upper one at 100-ml capacity. The test solutions are measured with a pipette. These pipettes deliver a total of 1-ml from the upper graduation mark and are calibrated in 1/10-ml divisions. Each pipette is to be used only for the test for which it is marked in the pipette case and is to be returned directly to its place when the test is completed.

For the SOAP-HARDNESS test, fill the bottle marked "hardness testing bottle" to the 50-ml mark with the water sample to be tested. Using the soap pipette, add 1/2 ml of soap solution to the water sample. Be sure you jot down the amount of solution added. Shake the bottle vigorously and place it on its side.

If no lather forms, continue adding soap solution in 1/2-ml portions, shaking the bottle and placing in on its side after each addition. As soon as a lather is obtained, allow the test bottle to remain undisturbed on its side until the surface of the lather begins to break enough so the water below shows plainly in the lather film. If the lather does not break, leave the bottle untouched for 5 minutes. Unless the water is very soft, nearly all the soap bubbles disappear after the first addition of soap. As more soap

is added, the break in the lather film becomes smaller and more time elapses before the break in the lather occurs.

If the lather surface remains unbroken after 5 minutes, it is considered a permanent lather and the test is completed. You then total the number of milliliters of soap required to obtain this lather and determine the hardness in ppm by multiplying this number by 20.

A very small amount of soap is required to produce a lather in water having no hardness, such as distilled water. This amount, known as the lather factor, varies with the type of soap used. This lather factor is normally placed on the label of the soap reagent bottle. With the strength of the solution used in the test kit, the lather factor should not exceed a few tenths of a milliliter. To obtain the correct soap hardness of the water, you should subtract the ml of lather factor from the total ml of soap used before making the calculation for hardness.

If more than 6 ml of soap solution are required to obtain a permanent lather, the test is repeated with a new sample of water diluted with zero-hardness water from the kit. To do this, first measure 25 ml of the water to be tested in a graduated cylinder and transfer it to the hardness-testing bottle. To this, add 25 ml of the zero-hardness water. Then repeat the test and, when completed, multiply by 40 instead of 20.

There are two alkalinity tests; one known as the TOTAL OR METHYL ORANGE (MO) ALKALINITY, and the other the PHENOLPHTHALEIN ALKALINITY. Few surface or ground waters show phenolphthalein alkalinity. Nearly all except acid waters show MO alkalinity. Methyl orange (MO) alkalinity tests will give the total alkalinity whereas the phenolphthalein test measures all of the hydroxides and half of the carbonates.

You start the MO alkalinity test by filling a test bottle to the 50-ml mark with a sample of the water being tested. Add 2 drops of methyl orange indicator solution. Place the test bottle over a white towel or other white surface so a change in the solution's color can be seen easily. If the solution becomes yellow, hydroxides, normal carbonates or bicarbonates are present. Begin adding sulfuric-acid solution with the sulfuric-acid pipette until the test sample begins to turn from a yellow to a pinkish red color. As you do this, write the total number

of ml of sulfuric-acid solution used. Multiply this number by 20 and you have the ppm MO alkalinity.

Start the phenolphthalein-alkalinity test by also filling a test bottle to the 50-ml mark with a water sample. Add 2 drops of the phenolphthalein-indicator solution. Place the bottle over a white towel or white surface. If no color forms in the sample, record the value of phenolphthalein alkalinity as zero.

If a pink color forms in the solution, add sulfuric-acid solution a drop at a time until the pink color disappears. Record the total number of ml of sulfuric acid used. Multiply this total by 20 and you have the ppm phenolphthalein alkalinity.

The CHLORIDE test is also made with a 50-ml sample of water. Add 3 drops of potassium-chromate (yellow) indicator solution to it. Then start adding silver-nitrate solution with the silver-nitrate pipette until the solution begins to change from a yellow to a definite reddish color. Record each ml of silver-nitrate used. Give the water sample a mild shaking after each addition of silver-nitrate solution by rotating the bottle back and forth. Multiply the total number of ml of silver nitrate required by 10 and you have the ppm chlorides.

In the SULFATES test, the sulfate value is found by trial, as the test merely determines approximate values. For this reason, it may be necessary to repeat the test several times.

You begin by testing for sulfates at 100 ppm. A clean test bottle is filled with the sample water to the 100-ml mark. Add 1 ml of barium-chloride solution with the barium-chloride pipette to the sample. Shake the bottle intermittently for 10 minutes.

Now tear a piece of filter paper into small pieces and place them in the solution. Shake this solution for 5 minutes, or until the paper becomes fluffy and gelatinous. Fold a filter paper into quarters and then line the cone of a funnel with it. Place the funnel and filter paper in a second bottle. Filter about one-fourth of the sample into the second bottle. Rinse the second bottle with this small portion of filtrate and discard the filtrate. Replace the funnel and continue the filtration, collecting about one-half bottle (50 ml) of filtrate.

Add 1 ml of barium-chloride solution to the filtrate with the barium-chloride pipette, shake for 5 minutes, and observe immediately for a precipitate or a clear solution.

If a clear solution is obtained, record the sulfates as less than 100 ppm. If an immediate precipitate or milky solution is obtained, the sulfates are greater than 100 ppm and a new sample must be tested for 200-ppm sulfate. This test is the same except that 2 ml of barium-chloride solution instead of 1 ml are added at the beginning of the test. The 1 ml of barium-chloride solution added after the filtration is not changed. For each succeeding test, add 1 ml of barium-chloride solution at the beginning of each additional 100-ppm sulfate test.

If a clear solution is obtained, the sulfates are less than the ppm tested for, and the sulfates are recorded as between the value of the test and that of the preceding test. If an immediate precipitate or milky solution is obtained, the sulfates are greater than the ppm tested for, and a new sample must be tested for the next higher value.

Flocculation

The jar test for flocculation is one that the Utilities Man will frequently perform. Into each of a number of jars or bottles you pour a sample of the raw water to be treated. Thoroughly mix various doses of aluminum sulfate, or ammonium alum and lime or soda ash, with these raw water samples, and then observe the size of the floc that forms, and its rate of settling.

It will be necessary to stir the water after the coagulant and alkali have been added, until small particles join with each other to form the large, jelly-like particles that are the floc. The smallest dose of the coagulant and alkali that produces a good floc and complete clarification indicates the ratio of chemical to raw water that you should use in treating the water supply.

Residual Chlorine

The use of orthotolidine for making tests for residual chlorine is described in NavPers 10656-C. However, a

few additional facts will help you in performing these tests, or in supervising their performance by lower-rated men.

Keep in mind that the only true measure of the effectiveness of chlorination is the bacteriological quality of the water after treatment, as indicated by residual chlorine. Remember, also, that the water must be tested at the point at which it is used. Maintenance of the proper residual for the distribution system does not necessarily mean that the same residual is maintained at the points of use; in its passage through piping, the water may become recontaminated.

Determination of residual chlorine cannot be made solely on the basis of the amount of chlorine applied to the treated water, because many varying factors are involved. For example, efficacy of chlorination depends upon types and concentrations of chlorine present; *p*H value of the water; types and densities of virus, bacteria, and protozoa, and their resistivity to chlorine; period of contact of organism and chlorine; and temperature of water.

Minimum residual chlorine requirements are higher for water containing cysts than for water containing bacterial organisms. Another distinction that must be made is that between residual in the form of free chlorine and residual in the form of chloramines.

Whether free chlorine or chloramines will be present after chlorination of the water depends upon the ratio of chlorine dosage to the ammonia-nitrogen content of the water. If this ratio is lower than 5 to 1, the chlorine will react to form chloramines. Further increase in the dosage will oxidize these chloramines, and produce free chlorine residuals. The "breakpoint" should occur when the ratio of chlorine to ammonia-nitrogen is 9 to 1.

If the residual chlorine is free available chlorine, and the *p*H value of the water is less than 7.0, chlorinate to obtain 0.2 ppm free chlorine residual after a contact period of 20 minutes. Increase this residual 0.1 ppm for each *p*H unit value above 7; that is, for *p*H 7.0 to 8.0, maintain 0.3 ppm, and for *p*H 8.0 to 9.0, maintain 0.4 ppm. Keep the *p*H value below 9.

Apply the chlorine continuously, and in such a way that thorough mixing with the water is ensured. In most cases, chlorination should be accomplished to the level of free chlorine residual, since chloramine residuals require that the chlorine contact time be not less than two hours.

Free chlorine is about 30 times as effective as chloramines in destroying bacteria, if the *p*H value of the treated water is 7.0 or lower. As *p*H increases, chlorination becomes decreasingly effective. It may sometimes be advisable to lower the *p*H value rather than to use excessive doses of chlorine.

Routine Control Tests

The medical officer at any Navy activity is responsible for determining if available water meets the established bacteriological and chemical standards. He will do most of the actual testing, and in advanced areas he will decide upon the treatment process that is required. Nevertheless, there will be many occasions when the Utilities Man will be called upon to perform routine control tests after the local situation has been analyzed by the medical officer.

In making these routine tests, you may be using a unit of measurement that is new to you. In water treatment, the weight of chemicals added to each gallon of water is such a small fraction of a pound that the grain is used as the unit of measure. Quantities are expressed as GRAINS per gallon. In larger chemical doses, quantities are expressed as POUNDS per million gallons. As there are 7,000 grains in each pound, 1 grain per gallon equals 1/7,000 pound per gallon or 143 pounds per million gallons. (1/7,000 x 1,000,000 = 143.) To obtain grains per gallon, divide the number of lb per million gallons by 143.

Dosages of coagulating chemicals are given as grains per gallon. Since 1 lb is equal to 7,000 grains, the dosage in pounds can be determined from this equation:

$$\text{Pounds of chemical required} = \frac{\text{gallons of water treated} \times \text{dosage in grains per gallon}}{7{,}000}$$

For field approximations, you may consider 1 grain per gallon as equal to 1/8 lb per 1,000 gallons.

Another unit of weight, in respect to the volume of water, is parts per million (ppm). This unit is an abbreviation of the expression: "parts BY WEIGHT of substance per one million parts BY WEIGHT of water." The word "part" refers to similar units and may be used to indicate any unit of measure. For example, 1 lb of alum per million pounds of water or 1 grain of alum per million grains of water are both expressed as 1 ppm. However, water is not measured by weight, so the weight of a gallon of water is used to convert pounds per million gallons to parts per million. A gallon of water weighs 8.34 lb, so one million gallons weigh approximately 8,340,000 lb. Therefore, 8.34 lb per million gallons equal 1 ppm.

Since 143 lb per million gallons equals 1 grain per gallon, and since 8.34 lb per million gallons equals 1 ppm, 1 grain per gallon equals 143 divided by 8.34 or 17.1 ppm.

The conversions are summarized in table 2.

Table 2.—Units of Measurement and Conversion Factors.

To convert	To		
	Grains per gallon	Parts per million (ppm)	Pounds per million gallons
	Multiply by		
Grains per gallon	1	17.1	143.0
Parts per million (ppm)	0.058	1	8.34
Pounds per million gallons	0.007	0.12	1

DISINFECTION OF MAINS, TANKS, AND OTHER UNITS

Dirt and waste material is introduced into wells, pumps, filters, water mains, and storage tanks during

construction or repair; surface drainage, or small animals, may cause additional contamination. Of course, the ordinary precaution of flushing a water system will be taken before the system is put into operation, but there can be no assurance of a really safe water supply until each unit has been thoroughly disinfected.

Wells should be disinfected after construction, after they have been cleaned out, and after equipment has been removed for repair. When the well is ready for operation (after any of these three conditions), it must be pumped to waste, until the water is free from turbidity; the proper amount of chemical should then be added, either in powdered form or as a concentrated solution.

Emergency disinfection in wartime may be accomplished by the use of hypochlorination units. However, these units will not be adequate for the removal of contamination caused by atomic, biological, or chemical warfare.

Disinfecting Agents

The chemicals that are used to disinfect a water system are the same as those used to disinfect water, but the strength and contact time are very different. Free chlorine, in gaseous, powdered compound, or liquid form, is the most satisfactory chemical. Grade A hypochlorite will probably be available; this contains 70 percent available free chlorine, and dissolves easily in water. If chlorine in the form of gas is used, there must be a chlorine-feeding device, with a competent operator in charge.

Besides the Grade A hypochlorite, other chlorination agents are: calcium hypochlorite, commonly called chloride of lime, which contains about 1/2 as much available chlorine, per unit weight of compound, as Grade A hypochlorite, and is less easily applied; and commercial sodium hypochlorite preparations such as Clorox and Zonite, which can be obtained in 5- and 10-percent solution strengths.

For large tanks or reservoirs, it may be more practical to apply chlorine by swabbing or spraying. The first step is to wash down the containers with a strong hose

stream of treated water. Then swab or spray all internal surfaces with a solution of at least 200 ppm available chlorine, and let it remain for at least 1 hour. The last step is to flush the chlorine solution to waste.

Remember that all hypochlorites have the effect of raising the pH of the water to which they are added. This reduces to some extent the effectiveness of the chlorine, and can be of considerable importance if the pH is raised to a value above 8.

The recommended dose of Grade A hypochlorite is 1 lb to 800 gal water, or to 100 cu ft of water; this results in a dose of about 100 ppm strength. For the sodium hypochlorite solutions, the recommended dose is 1 gal of 10-percent solution to each 1,000 gal water; this will give 100 ppm free chlorine.

Volume of water in the unit to be disinfected must be computed before the proper chlorine dosage can be determined. However, the dosage depends also upon the period of contact, and the amount of jute, untarred hemp, and organic chlorine-consuming matter present.

Flush the system to remove sediment, then fill it with the required mixture of calcium hypochlorite and treated water. The disinfectant is allowed to remain in the system for at least 48 hours; it is then drained off, and examined for residual chlorine.

Safety Precautions

The first precaution to take in disinfecting a tank or a system is to ensure that adequate protective measures have been taken against fire at the station. The second safety precaution is to ensure that a bacteriological examination be made of the water after disinfection.

Samples collected immediately after disinfecting of the water may not be representative; therefore, it is desirable that further samples be collected several days later, so as to check on the water that is being delivered under normal conditions of operation and use. If possible at all, no domestic use should be made of the water until the repeated bacteriological examination shows it to be safe. If the water must be used, for drinking or for cooking purposes, it should first be boiled.

MAINTENANCE OF EXISTING SUPPLIES

The standards for water used for drinking or for culinary purposes by Navy personnel are in general the same standards as those adopted by the Public Health Service, and in effect in all American communities. Except in cases of emergency treatment of water in field operations, any water distribution system maintained for Seabee units must meet all the requirements of the physical and chemical standards of water supplies at continental installations.

Maintaining these standards involves taking all necessary precautions when a distribution system must be constructed, or when water is drawn from a municipal system in a foreign country (particularly when that municipal system has been exposed to wartime damage). It also involves the proper care of structures, supplies, and other equipment used in the distribution or the purification of water.

Construction of a Distribution System

Safe and adequate supply of water at a naval shore activity may involve the construction of a distribution system, whether extremely simple or complex. Operational procedures in connection with such a system will vary according to the means used in collecting, storing, and treating the water.

The first requirement, naturally, is the site; it should afford absolute certainty of a safe and continuous supply. The second requirement is that it be constructed and operated in accordance with approved engineering practice. The third requirement is that it be operated with the greatest possible economy consistent with the first and second requirements.

Once a satisfactory water supply for the needs of a camp or an installation has been located, the work of developing it begins. In the interests of conserving manpower and materials for other undertakings, no work should be done unless it is necessary for furthering the type of development that is basic to a safe and adequate system. These basic aims may be stated as follows:

1. Increase the quantity of potable water available.
2. Improve quality.

3. Keep distribution problems to a minimum.
4. Keep maintenance requirements to a minimum.
5. Improve security.
6. Improve the living conditions of the personnel at the installation.

Extent of development depends upon probable duration of occupancy, as well as upon manpower and equipment that can be employed. Water sources of front line installations may require only as much development as is consistent with safe water supply for military needs; in rear areas, or where an installation is to be permanent, much more work will normally be undertaken.

The order in which improvements are made depends upon site conditions and the tactical situation. A development schedule actually used in developing a water supply on an island in the South Pacific may serve as a guide:

FIRST DAY:	Equipment installed and water distributed. Vegetation and debris cleared away from water source. Drainage ditches dug.
SECOND DAY:	Bulldozers used to clear a turnaround. Traffic signs erected.
THIRD DAY:	Storage tanks (canvas) erected. Construction started on a pipeline to division service area.
FOURTH DAY:	Elevated platform installed for 3,000-gal storage tank.
FIFTH DAY:	Revetments erected around equipment, to give protection against sniper fire.
SIXTH DAY:	Eight-mile pipeline completed.
SEVENTH DAY:	Bulldozer completed cutting a one-way road to water point.

Drought in the area, or prolonged peak or emergency use, may threaten supply, but by efficient management these threats must be neutralized, and quantity and quality safeguarded.

Decreased yield may be caused by:

1. Receding ground water level.
2. Cave in of a water-bearing stratum, or its filling with sand.
3. Interference by other wells.
4. Leaky casings or delivery pipes.
5. Seepage or leakage around reservoirs or dams.
6. Clogging of a well screen or gravel packing.

When canvas tanks are used for storage, they must be raised from the ground, so that air can circulate beneath them. Low platforms, such as that shown in figure 8-6, can be used; these can be dismounted and used again at another site.

Elevated platforms for storage tanks improve distribution; the water can be gravity-fed from storage to standpipes and to distributing nozzles. If lumber is not available, platforms may be constructed of concrete. Empty fuel drums may be assembled to form an emergency platform.

Many distribution problems may be solved by using standpipes or rigid pipelines. The pressure in a standpipe

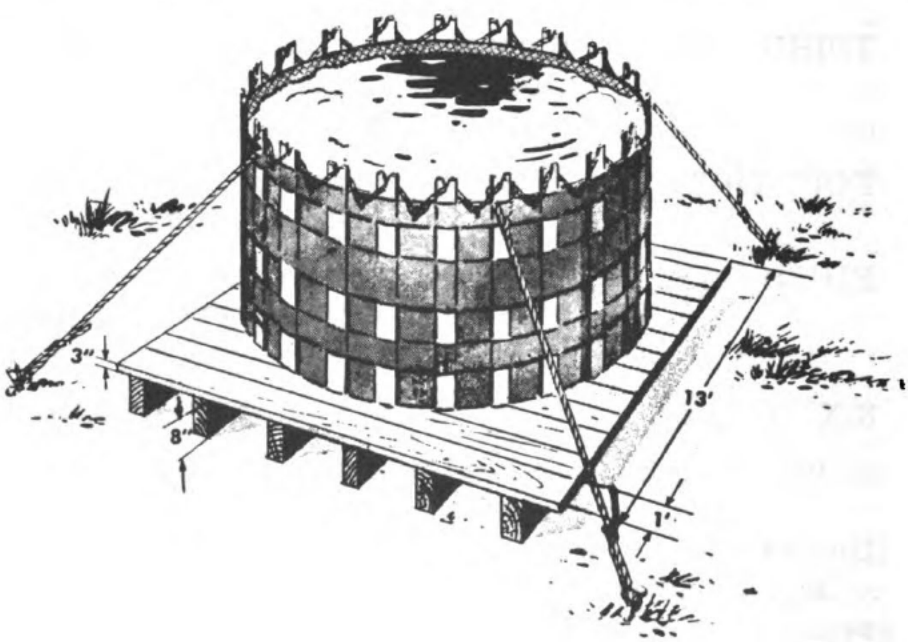


Figure 8-6.–Canvas storage tank mounted on ground platform.

must be sufficient, and the outlet high enough to service tank trucks. Pipelines (salvaged pipe from damaged water-works may be utilized) can be used to convey water over terrain impossible to trucks. However, the pumping sets furnished with portable units will probably be incapable of developing sufficient pressure for such pipeline systems; you will need a power-driven pump of greater capacity.

If conduits are used, those carrying treated water must not be connected with those carrying partially treated or raw water, nor should there be a common wall between them. If rewash of filter-to-waste conduits are connected to a drainage conduit, the installation of a one-way gap delivery connection will protect the rewash conduit from backsiphonage (that is, backflow of contaminated water from a cross connection).

Water From Municipal Systems

Municipal sources are usually well-developed, with pumping, filtering, and treating equipment, distribution tanks or reservoirs, and mains. In times of military action, these waterworks may be damaged by shellfire, or they may be contaminated by a retreating enemy; the quality of the water, therefore, should be carefully tested before any use is made of it.

If a system has been badly damaged, so that not only is the water polluted, but the distribution system also fails to operate, you may be able to use hydrants as intake points, by fabricating a pipe adapter to connect the hydrant and the field water purification unit. Where water is turbid, or the pressure in the mains is low, it is best to install a sedimentation tank between hydrant and purification unit.

Even in a damaged system, the mains may be capable of yielding large quantities of water if they can be tapped at a low point in the distributing system. Breaks in sewage pipes may have caused contamination, so the water must be carefully treated.

A municipal water system that is safely used by local inhabitants may be anything but safe for incoming military personnel. It is necessary to make sure that any local supply meets Navy-established standards. (This

can be done by applying the tests described in NavPers 10656-C.) Further, with the peak demands made on a local system during a period of military occupation, loss of pressure in municipal supply lines is likely to occur, with resulting backflow of polluted water from tanks and plumbing fixtures. In any system, contamination may result from backflow of waste water or drainage, because of poorly designed cross connections.

It is impossible to lay down hard and fast rules about work to be accomplished in connection with the operation and maintenance of an existing waterworks system. Whatever records are available can be used as guides; but it is extremely important that all indicated tests be made upon the water itself, to ensure that it will really be a usable source.

Where there is any difficulty in ensuring the required safeguards for conduits, it may be advisable to carry the line through the open. Such an open line is much easier to inspect, and to repair. Use cast iron pipe, and make sure that all joints are tight.

Management of a waterworks system, either existing or newly constructed, requires periodic inspection to check on waste and leakage; repair and upkeep as indicated; and a measure of laboratory control. This involves a system of record keeping on all significant factors. For example, maps and drawings must be kept up to date, and design elements must at times be modified (and the modifications recorded) to obviate the functional deterioration that is bound to occur.

Operating reports must be maintained as a guide to subsequent procedures. The manufacturer's operating and maintenance instructions for various parts of a system should be kept with the equipment to which the instructions relate, and duplicate copies should be kept on file.

Care of Equipment

To maintain equipment in satisfactory operating condition, and to detect and remedy minor faults before they develop into major defects, you should follow a systematic plan for regular inspection, cleaning, lubrication, and adjustment. The specialized tools with which you repair and adjust equipment are as important as the

equipment units themselves; keep them properly cleaned and lubricated, and in an easily accessible place.

Make a regular inspection of wells, settling tanks, filters, and other functional units of water pumping and treating equipment. Check masonry for chipping, cracks, and breaks; check wooden structures for signs of rot or warping.

Use safe cleaning agents, such as kerosene and dry-cleaning solvents. Gasoline, naptha, and benzine are hazardous because of their low flash points; benzine has the added risk of being extremely toxic.

Even when using kerosene, you must keep the work space well ventilated, and avoid spillage or exposure to flame. Store kerosene in a metal container, capped and properly marked, in an unheated space.

When you have used dry-cleaning solvents, be careful not to put equipment back into use until all traces of the solvent have completely evaporated from it. As soon as your cleaning rags are dry, immediately dip them in oil or lubricant.

Painting metal surfaces is one of the best means of protecting them against corrosion, but the paint should be applied before corrosion becomes severe. Clean the surface first, sandblasting it if necessary; use corrosion-preventive compound in moist places, and in pits where paint would not last. On surfaces where the drying temperatures are less than 40 F, use specially prepared paints. Use creosote or similar preservatives, rather than paint, on wooden surfaces at or above a waterline.

Good lubrication practices are extremely important in maintaining equipment in good operating condition. Inadequate lubrication can cause damage to wearing surfaces, but too much lubrication can cause antifriction bearings to overheat, and may damage grease seals, or motor windings. Follow the specific instructions on types of oil or grease to be used, as given by the manufacturer of the equipment. Keep lubrication containers covered, so that no dust or grit will enter.

Special precautions must be taken when equipment is to be removed from service for an extended period of time. Dismantle the equipment, and apply suitable oils, greases, and rust- and corrosion-preventive compounds to all surfaces.

Have safety equipment available at all times. This equipment should include safety harnesses, ropes, ladders, gas masks, protective clothing, safety lamps, explosimeters, and indicators for toxic gas and oxygen deficiency. Never allow anyone to enter a tank or enclosed chamber until the air has been tested for the presence of toxic gas, and for oxygen deficiency.

QUIZ

1. What are the 4 generally employed processes of purification?
2. How is emergency disinfection of canteen water accomplished?
3. What is the purpose of the chemical kit which accompanies each Lyster bag?
4. The purification process that should be employed to remove bacterial contamination is
   (a) coagulation
   (b) sedimentation
   (c) chlorination
   (d) flocculation
5. Blistering agents introduced into a water supply by enemy action can be removed by the application of
   (a) activated carbon
   (b) soda ash
   (c) chlorine
   (d) alum
6. Since sedimentation succeeds only in clearing water of nonliving suspended solids, why is it frequently used in conjunction with coagulation and chlorination?
7. Why are sedimentation basins usually long and narrow?
8. Certain chemicals are useful in the coagulation process, since they form jelly-like precipitates which
   (a) immediately sink to the bottom of the basin
   (b) are readily soluble in water
   (c) are good agents for stabilizing pH value of the water
   (d) absorb suspended matter and carry it to the bottom of the basin
9. What is the adverse effect of alum when it is used for coagulating water?
10. What purpose is served by backwashing a filter bed?

11. Best results from the use of a sand filter will be obtained when the filter is operated at
    (a) a steady rate
    (b) fast and slow rates, intermittently
    (c) a slow rate for the first hour, then a rapid rate thereafter
    (d) a rapid rate for the first hour, then a slow rate thereafter
12. What is the normal period between washes for a rapid sand filter?
13. In storing filtered water, what is the chief precaution to be taken?
14. The customary method of judging the effectiveness of chlorination applied to polluted water is by measuring the
    (a) ratio of water and applied chlorine
    (b) turbidity of the water after treatment
    (c) actual chlorine dosage
    (d) residual chlorine
15. What is the recommended chlorine dosage for water with a low organic content?
16. Why does the Navy use chlorine in a powdered compound form, for disinfecting water?
17. In the use of chlorination equipment, automatic control of chlorine feed is necessary whenever the
    (a) rate of flow of water is constant
    (b) rate of flow of water varies over a 50-percent range
    (c) chlorine is being applied in liquid form
    (d) chlorine is being applied in the form of gas
18. What is the power source by which an Army-type hypochlorinator is operated?
19. When an excess of hydrogen sulfide gas must be removed from water, the recommended process is
    (a) increase of the H-ion content
    (b) decrease of the alkaline content
    (c) aeration
    (d) hypochlorination
20. Why must water be chlorinated after distillation?
21. What are the 2 general types of distilling plants?
22. How should distilling plants be protected in cold weather?
23. What is the chief disadvantage of distilling plants?
24. Which are more dangerous to health, the suspended impurities in water, or the dissolved impurities?

25. The recommended field treatment for removing taste and odor from a water supply is the use of
    (a) Lyster bags
    (b) soda ash
    (c) aeration and activated carbon
    (d) sedimentation and filtration
26. The preferable range of temperature for drinking water is between
    (a) 35 and 40 F
    (b) 40 and 50 F
    (c) 55 and 60 F
    (d) 60 and 70 F
27. The soap-hardness test is made on a water supply to test for the amount of
    (a) calcium and magnesium salts
    (b) chloride ions
    (c) hydroxides
    (d) sulfates and nitrates
28. How much more effective in destroying bacteria is free chlorine than chloramines at *p*H 7.0?
29. What is the normal relationship between chlorination and the *p*H value of water?
30. After a well has been newly constructed, or after it has been cleaned out, the water should be pumped to waste until what condition is obtained?
31. What is the primary purpose for which hypochlorination units are used?
32. In the computation of proper chlorine dosage, what are the 3 chief factors that must be considered?
33. When a distribution system is to be constructed at a new base, what must be considered as the first requirement?
34. When canvas tanks are used for storage of water, why is it desirable that they be placed on raised platforms?
35. What 3 safety precautions must be taken in a work space where kerosene or dry-cleaning solvents are being used?

CHAPTER 9

SEWAGE AND REFUSE DISPOSAL AND PEST CONTROL

The health and well-being of the personnel at any Navy installation, and especially at an off-continent base, will depend to a great extent upon the sanitation standards that are maintained. An organized sewage and disposal system, and effective control of insects, rodents, and related pests, are essential both for the protection of men and the proper care of buildings and materials.

Health, safety, and comfort can be ensured if high standards of sanitation and of pest control are established, and observance of these standards made routine. Unscheduled inspections, carried out at frequent intervals, should disclose any necessity for additional instruction or greater caution.

The primary responsibility for establishing these sanitation standards, and for planning, constructing, and maintaining the necessary procedures for sewage disposal and pest control, are the functions of the commanding officer of each naval installation. Normally, these responsibilities are delegated to the medical department and the public works department, as appropriate.

The Chief Utilities Man, or the Utilities Man first class, however, will frequently be the key man in operating and maintaining available equipment for pest control, and in utilizing the various methods of sewage and disposal. For this reason, therefore, you should acquire as much information as possible about the sanitation and

health problems at your base, and the most efficient methods of eliminating or controlling them.

This chapter should provide you with sufficient information to enable you to handle the types of problems that most commonly arise. For additional information, you will find it very helpful to have a copy of the Bureau of Yards and Docks technical publication on sewage systems and refuse disposal, and the manual on insect and rodent control issued jointly by the Departments of the Air Force, Army, and Navy. The exact titles of these three manuals are:

Refuse Disposal, Technical Publication NavDocks TP-Pu-1, 1 September 1952.

Insect and Rodent Control, AFM 85-7, TM 5-632, NavDocks TP-Pu-2, 1 February 1956.

Sewerage Systems, Technical Publication NavDocks TP-Pw-15, 1 May 1952.

The first of these three manuals contains instructions for disposing of all solid forms of waste resulting from human activities, with the exception of dehydrated sewage sludge, and waste from industrial and construction processes—for example, oil sludge, excavated earth, wreckage from buildings, and discarded explosives.

The second manual contains a comprehensive discussion of the various insects and rodents that are a hazard to health, efficiency, and morale of personnel, and a source of property damage, at Defense installations. The supplies and equipment required in the use of insecticides, fumigants, and fungicides, the safety precautions for mixing, storing, and applying these remedies, and the types of construction that provide a breeding place for pests, are all described in considerable detail.

The third manual contains information on sewerage and industrial waste collection, treatment, and disposal systems.

Actual problems encountered will depend upon the climatic conditions and topographical features prevailing at a given base, and upon the stage (emergency, temporary, or permanent) to which the base is to be developed. However, this training course, supplemented as necessary by the three publications just described, should enable you to find the solution for any condition that may arise in the

performance of your assigned duties with respect to pest control, sewerage, and refuse disposal.

EMERGENCY SEWAGE FACILITIES

At initial landings, or during brief halts on the march, primitive methods may be used for the disposal of human wastes. A small hole, dug out with an entrenching tool or a bayonet, is usually satisfactory; after depositing the feces, the men should cover these holes, to a depth of several inches, with earth.

During a prolonged halt, as for a meal, it is customary to set a sanitary detail to digging straddle trenches, and their location is pointed out to the men. These trenches should be confined to as small an area as possible, and when the column is again on the march, the sanitary detail should remain long enough to fill these trenches with earth, and mark their location.

TEMPORARY SEWAGE FACILITIES

For a site that will be occupied for a few days only, the simplest sanitary methods of waste disposal may be utilized. When the development of a permanent or a semipermanent base is undertaken, waste disposal problems become more complicated, and the public works officer or the designated CEC officer will have the responsibility for planning and constructing facilities.

However, even in the case of the simplest facilities, construction and maintenance must be carefully planned. At a base where relatively primitive methods must be followed in the disposing of waste, intestinal and insect-borne diseases are a constant hazard to the health and efficiency of the men.

Types of Facilities

At a temporary base, facilities usually consist of straddle trenches, urine soakage pits, latrines, and chemical toilets. If there is a sufficient water supply, flush-type toilets should be provided. Water from showers and lavatories can be led to a dosing tank, and then utilized to flush out latrine channels.

STRADDLE TRENCHES are usually located about 3 ft apart, and may be anywhere from 3 to 10 ft long, depending upon the number of men who must be accommodated. The earth that is removed in making the trenches should be piled up at the ends; planks laid alongside will provide a good foothold. When these trenches must be built in an inhabited locality, they should be screened from view. Toilet paper should be protected from the weather with a canvas cover, or with cans.

When a trench is filled to within a foot of the ground level, it should be sprayed with oil, DDT, or sodium arsenate, and then filled and mounded over with earth.

LATRINES should be located on the opposite side of a camp area from the galley and mess hall. The ground must be well drained, but the drainage must not be such that it might contaminate a source of water supply. In limestone, coral, volcanic rock, or gravel, a latrine pit can cause serious ground water pollution.

A drainage ditch should be dug around the entire latrine enclosure, and should connect with a channel to carry off surface water. Flooding of the drainage ditch must be guarded against in areas subject to heavy rainstorms. In selecting the latrine location, it is also necessary to avoid interference with desirable areas for future site development.

The number of latrine seats or spaces should be sufficient to provide one seat for each 10 to 20 men. A canvas screen will serve to protect it from view, and a tent or other covering will give protection from the weather. A lighted lantern should be hung at each latrine at night, unless concealment is a military necessity.

Where it is expected that a latrine will be used for less than one week, a 3-ft depth is sufficient. Add one more foot for each additional week of anticipated use. A deep pit latrine, if carefully constructed, may be safely used on a base of semipermanent construction. Bored-hole latrines, made with a post-hole augur to a depth of 15 to 20 ft, are almost flyproof.

After water pollution, the danger of fly breeding is the chief thing to guard against. Fly-tight boxes, made in units of four, can be prefabricated and assembled and set up as needed. Several units can be put together and bolted end to end. Figure 9-1 illustrates

the way in which such units can be constructed and assembled.

A deep pit that penetrates well below the water level will prevent fly breeding, and will prevent the surface scattering of solids. Poles or planking can be used to crib these pits, to avoid cave-ins. Oil drums, with one or both ends removed, can be utilized as cribbing.

Where the pit cannot be made deep enough to prevent fly breeding, the surrounding ground must be treated.

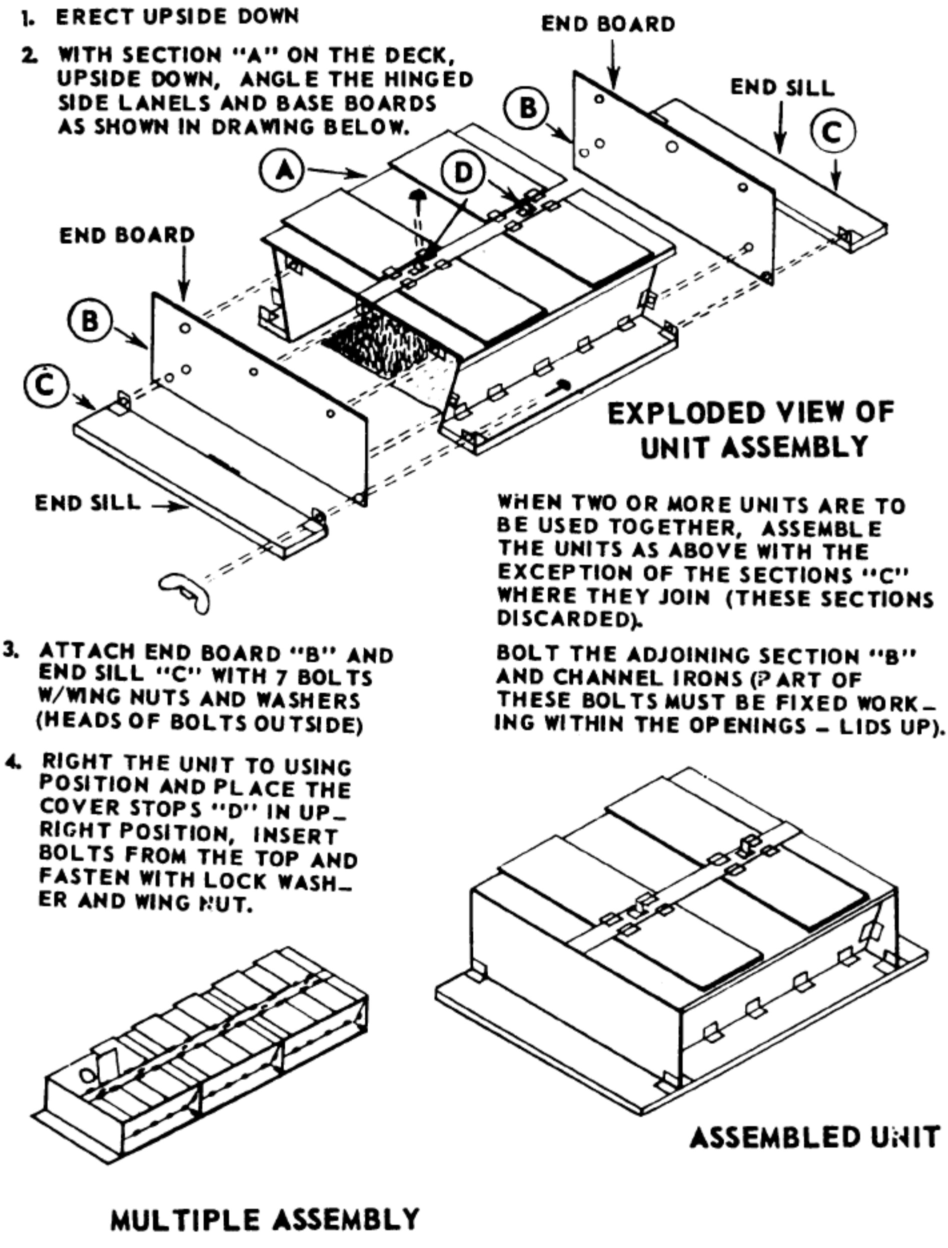


Figure 9-1.–Latrine box developed by the Marine Corps.

Not only the interior of the pit, but also a 4-ft wide area around it, must be periodically sprayed with DDT. After the latrine box has been placed over the pit, oiled or moistened earth should be tamped tightly around the perimeter of the box. All cracks in the box must be made fly-tight by means of strips of wood or of cloth packing. Ventilation openings must be screened, and these screens painted every 3 or 4 weeks with DDT solution.

When a pit has been filled to within 18 in. of ground surface, or is to be abandoned, the pit should be thoroughly sprayed, and the excavation backfilled. The surface can then be mounded over to allow for future settlement. If the military situation permits, the location of the pit should be marked with a placard that gives the date and the organization name.

URINE SOAKAGE PITS can be made without any special preparation in soil that is pervious, or that can be made pervious by blasting. The urinal piping should extend for at least 1 ft into the pervious material. Where soil is impervious, a pit 4 ft deep and 4 ft square should be dug, and then filled with broken stone and brick; flattened tin cans and broken bottles can also be used as filling. It will probably be better not to provide any ventilating shafts through this rubble, as shafts are likely to increase the odor emanating from the pit. The funnels should be small, and should not lead to pockets where urine may collect.

If the soil near the ground surface will absorb urine, and if it is not feasible to excavate to a depth of 4 ft, a soakage trench may be constructed. This should consist of a central pit about 1 ft deep and 2 ft square, with trenches leading from each corner. The trenches or ditches should have a downward slope, to a depth of 18 in. at the outer ends; they should be about 6 ft long, 1 ft wide, and 1 ft deep at their junction with the central pit. Like the urine soakage pit, they must be filled with some type of pervious rubble.

Soakage pits or trenches should be surfaced with oil-soaked burlap, and then covered with earth. When they are abandoned, all aboveground projections of piping must be removed, and the openings filled with earth.

URINE TROUGHS may be mounted directly above soakage pits, or erected in an adjacent enclosure and connected to the pit by means of suitable piping. If a

latrine pit is located in unusually porous ground, troughs may be connected to it instead of constructing separate urine pits. However, urine in the latrine pit causes offensive odors, so it should be kept to a minimum.

A urine trough may be constructed of tinned or galvanized iron or of wood. If made of wood, it should be lined with tar paper and made watertight. The trough should be U- or V-shaped in cross section, and sloped toward the outlet so that it will drain completely. The outlet should be protected by a wire-mesh insert to prevent foreign material from entering and clogging the drain piping. The trough should be approximately 10 lineal feet per 100 men.

If the facilities are to serve 50 men or less, connections to the pit may be 2-in. drain pipes, terminating at the top in funnel inlets. Funnels may be of metal or tar paper and should be as small as possible. They should be protected against clogging by a wire-mesh insert, or by filling them with grass or straw. Large areas exposed to urine make the odor problem worse.

CHEMICAL TOILETS have been to a great extent replaced by pit or by flush type latrines. The necessity for keeping chemical supplies on hand, and the risk of chemical burns, are decided disadvantages. However, this type of toilet affords a sanitary method of disposing of human wastes, since the combination of caustic soda and water acts to kill all bacteria, and to liquefy some of the solids.

To operate this type of toilet, you should charge the tank with 25 lb of caustic soda for each seat, and then fill it with water. Make sure that the water comes above the lower edge of the drop-tube agitator and manhole shafts, so as to provide a water seal and prevent the escape of odors. Maintaining a water seal, and operating the agitator after the toilet has been used, are essential for proper sanitation.

The tanks of chemical toilets should have gravity drains. Failing this, it will be necessary to empty them by pumping or bailing. The wastes from these toilets must not be placed in septic tanks, but should be either buried or barged to sea.

Maintenance of Facilities

Remember that the operation and maintenance of sanitary facilities will be your responsibility. The most

careful planning of the medical and the public works departments could be rendered useless by a lack of proper care on your part.

The following sanitary measures are suggested as particularly important:

1. Supply ample toilet paper.
2. Burn out the paper twice a week. Do not use gasoline, but sprinkle lightly with kerosene or diesel oil.
3. Keep boxes and enclosures fly-tight.
4. Keep lids closed.
5. Paint all screens once a month with DDT solution.
6. Scrub seats and urine troughs daily with soap and water, and twice weekly with a disinfectant.
7. Spray latrine pits daily with oil, or else treat them twice a week with PDB (paradichlorobenzene), or spray with a sodium arsenate or DDT solution.
8. Do not contaminate the seats with oil or poisonous insecticide solution used to treat the pits.

SEWAGE

The most sanitary method of removing liquid wastes from the vicinity of habited areas is by flushing into a sewage system. Where the soil is pervious, and where the volume of water from showers, lavatories, galleys, and toilets is small, the sewage may be passed through settling tanks and disposed of by absorption into the soil.

As water supply facilities and water consumption increase, a system of pipes and sewers must be provided to convey waste liquids to a point where they can be emptied into a natural body of water. In some cases, the sewage will have to be treated or altered, if it is to be disposed of without creating a nuisance, or becoming a health menace.

The construction of these sewers is an important factor in ensuring the health of the personnel. Proper operation and maintenance, once the system has been established, is equally important. If there are operating manuals for specific equipment, use them as guides in deciding how often the various maintenance services are required. Keeping your own records of the maintenance work done on a system can also be very helpful.

Sewers

Vitrified clay tile, concrete, or cast iron pipe can be used in sewer construction. The ditch in which the pipe is to be laid must be dug to an adequate width and depth. The ditch width should be at least 2 ft for pipe from 8 to 15 in. in diameter; for 18-27 in. pipe, width of ditch should be 3 ft or more; for pipe 30 in. or over, width of ditch should be 4 ft. or more. Minimum size of pipe, regardless of the quantity of sewage, will probably be 8 in., although for house connections 6-in. pipe can be used.

If there are lateral trenches, they should be dug after the main ditch has been dug. All ditches should be laid out, as far as possible, in a straight line, and should be provided with a firm base upon which the pipe can be laid. In swampy land, the base may be of sand tamped into the ditch, or of poured concrete.

When the pipe is to be embedded in concrete, cast iron pipe should be used because of its strength. In most other cases, vitrified clay pipe is preferable. In non-rock soils, asbestos cement pipe may be used, but neither asbestos cement nor concrete should be used where the pipe must pass through soil or water that contains 0.1 percent or more of the sulfate-type salts.

Drainage pipes must be at least 2 ft underground, to prevent freezing of the sewage and to protect the pipe itself from damage due to traffic. Where extra heavy traffic, or severe cold, is expected, this minimum pipe depth should be increased.

Where a drainage line crosses a fresh water line, the drainage pipe must be at least 2 ft below the fresh water line. Cast iron pipe should be used for at least 10 ft on either side of the crossing point, and there should be no joint immediately below the water pipe.

Where a drainage line runs in a direction parallel to that of a fresh water line, it is best to have the two pipes at least 10 ft apart. However, if the bottom of the fresh water pipe is at least 1 ft above the level of the top of the sewer pipe, a distance of 6 ft between the pipes will be adequate.

Bends in the pipe will sometimes be necessary, but the curves should be gradual. A uniform gradient is desirable; if the slope is such that it will provide velocities

of 2 or 3 ft per second, the systems will be to a large extent self-cleaning. All joints should be sealed to prevent leakage of the sewage, and also to prevent seepage of ground water into the system.

Manholes in a sewer line should be of brick or concrete. The diameter at sewer line level should be 4 ft, and the distance between manholes should not be more than 300 ft for 8-in. pipe. For larger pipe, the distance can be increased accordingly; for example, manholes for 10-15 in. pipe are usually provided at 400-ft intervals, and for 18-48 in. pipe they may be 500 ft apart.

To ensure that sewers are maintained in good operating condition, it will be necessary to regularly inspect them for broken sections, clogging, and other defects. Sections between manholes can be inspected by the aid of a flashlight and a mirror. The defects that occur most often are as follows:

1. SLUGGISH FLOW, SEPTIC SEWAGE, OR AN ACCUMULATION OF SEWAGE SOLIDS. These defects arise where there are obstructions in the system, or where the gradients are not well planned; they may also indicate that periodic flushing of the sewer has not been maintained.

2. EXCESSIVELY DILUTED FLOW IN THE SEWERS. This usually indicates that storm water or ground water has seeped into the sewer system. Raise the grade of the manhole covers, if necessary, to prevent water from entering the system.

3. SAND, MUD, OR GRIT. This indicates loose sewer joints or breaks in the sewer pipe.

4. BROKEN MASONRY AROUND A MANHOLE, COVERS THAT DO NOT SEAT PROPERLY, UNSAFE STEPS. These are construction defects that are easily remedied.

5. GASOLINE OR OIL TRACES IN THE SEWERS. These usually manifest themselves as oil slicks on the sewage surface, or as odors around the manholes. If signs of gasoline or oil are found, work back toward the head of the system, inspecting each manhole, to locate the source of the contamination.

6. EXPLOSIVE OR OBJECTIONABLE GASES OR VAPORS. You may need an explosimeter to test for this type of defect. Be careful not to use open flame, even from a lighted match.

In a later section in this chapter, you will find a discussion of the explosion hazards in sewage treatment plants. Take all the necessary precautions before working on any part of a sewer system.

Tanks

Tanks in a sewage system are used to remove the settleable matter. This matter sinks to the bottom of the tank, and undergoes gradual decomposition, until it becomes inoffensive. The sludge can then be removed for burial or dumping at sea.

SETTLING TANKS are usually constructed of reinforced concrete, and have a depth of about 6 to 10 feet. The length of the tank should be 3 to 5 times its width. Flow of sewage through the tank must be maintained at low velocity to give the heavy matter time enough to settle. In tanks that are over 8 ft wide, inlet baffles are used to promote a uniform flow over the cross section of the tank.

The sewage in a settling tank will usually consist of a top layer of scum, a layer of digesting solids near the bottom of the tank, and an in-between zone of relatively clear liquid, called effluent. This situation arises from the fact that methane and other gases are produced during the decomposition of the sludge. The rising gas will lift solids, some of which will fall back to the bottom of the tank when the gas is released; the remaining particles form the scum.

It is the middle zone of the sewage that should be withdrawn from the tank. The effluent, therefore, should pass under a grease scum baffle before being withdrawn over the outlet weir. The floating grease and solids, since they give rise to objectionable odors, should be removed daily. In hot weather, removal should be effected twice a day. As for the sludge at the bottom, it should be removed daily, and digested in separate digestion tanks. In most settling tanks, this removal of sludge is done by mechanical bottom scrapers.

SEPTIC TANKS are used at advanced bases where it is difficult to obtain mechanical equipment. They have the advantage of combining the settling and digestive processes, but the gases that are produced may raise the digesting solids high enough so that they will pass out of

the tank with the effluent. Where there is a rapid development of these gases, the effluent may contain more suspended matter than does the influent.

Septic tanks and field piping systems are provided in two functional components; one component is designed for a maximum of 250 persons, the other for a maximum of 1,000 persons. These tanks can be used to reduce the rate of clogging of soakage pits, sand filters, and subsurface tile disposal fields, and to prevent the formation of sludge banks in small streams or bays. Although they are useful for preliminary treatment of sewage, they should not be considered as capable of accomplishing a degree of purification that would satisfy good health requirements.

IMHOFF TANKS are so constructed that there cannot be a rise of settled matter during the gasification process. The solids settle first in an upper-central compartment of the tank, then pass through slots into the lower part. The sludge compartment should have a capacity of 3 cu ft per person. In estimating the volume of the sludge compartment, you should start from a plane 18 in. below the slots from the upper compartment.

Gas wells must not be less than 2 ft in width, and should comprise at least 1/5 of the horizontal area of the tank. When scum in the gas vent reaches a depth of about 8 in., it should be broken up and removed.

The Imhoff tank is capable of removing from 40 to 70 percent of the suspended matter. It also effects a 25 to 40 percent reduction in biochemical oxygen demand—that is, in the quantity of dissolved oxygen that is required to stabilize sewage solids.

All types of settling tanks require proper maintenance. They should not serve as catch basins for rain water, surface drainage, or liquid wastes that do not require treatment. Excessive amounts of grease should not be allowed to enter. The tanks must be inspected from time to time, to check upon their operation and to determine the depth of accumulated sludge and scum.

Sludge must be removed at least once a year; oftener if necessary. The matter from a combined settling and digestion tank may contain disease-producing bacteria in large numbers, so the disposal method must be a careful one. If possible, first dry the sludge on sand beds, and

then dispose of it in a seepage or disposal pit. If it is to be emptied into a body of water, make sure that the water area is sufficiently large to dilute the sludge to a point where it will be harmless.

Absorption

Disposal of liquid wastes by absorption is feasible only in areas where the soil is pervious, where the water table is never too close to ground surface, and where the volume of waste is small. Dig a small test hole about 1 ft square, and of the same depth as that planned for the disposal trenches. Fill this hole with water, to a depth of at least 6 inches, and observe how long it takes for the water level to drop a specific distance. This test will furnish a good indication of the absorptive quality of the soil.

A soakage pit or trench can then be dug to the dimensions required in terms of volume of waste and absorption capacity. Water from the laundry and galley, and from showers and lavatories, can be drained off in this way. However, any liquid waste that contains an appreciable amount of suspended matter should be given settling treatment before it is drained into the soil.

In making an absorptive test, have the bottom of the test hole at the level of the absorption area. Capacity may be estimated from the figures in the following table, provided that the hole is roughly 1 ft square, and is filled with water to a height of 6 in.

Table 3.—Absorption Rates

Length of time required for water to fall 1 in.	Estimated absorption capacity (gal per day)	
	Per sq ft of bottom of subsurface trench	Per sq ft of percolating area, seepage pit
1 minute	4.0	5.3
2 minutes	3.2	4.3
5 minutes	2.4	3.2
10 minutes	1.7	2.3
30 minutes	.8	1.1
60 minutes	.6	.9

Continue the test long enough to saturate the soil around the pit, because while dry, the soil absorbs water more readily, and over a short period of time this may give an erroneous impression of absorption capacity. If the area is one that has a long rainy season, try to make the test during that season; in any event, make due allowance for rainy season conditions.

If subsurface tile fields or cesspools are used, the waste liquid can be conducted into the upper layers of the soil through a system of open-joint tile or concrete pipe. The illustration in figure 9-2 provides a few hints for the

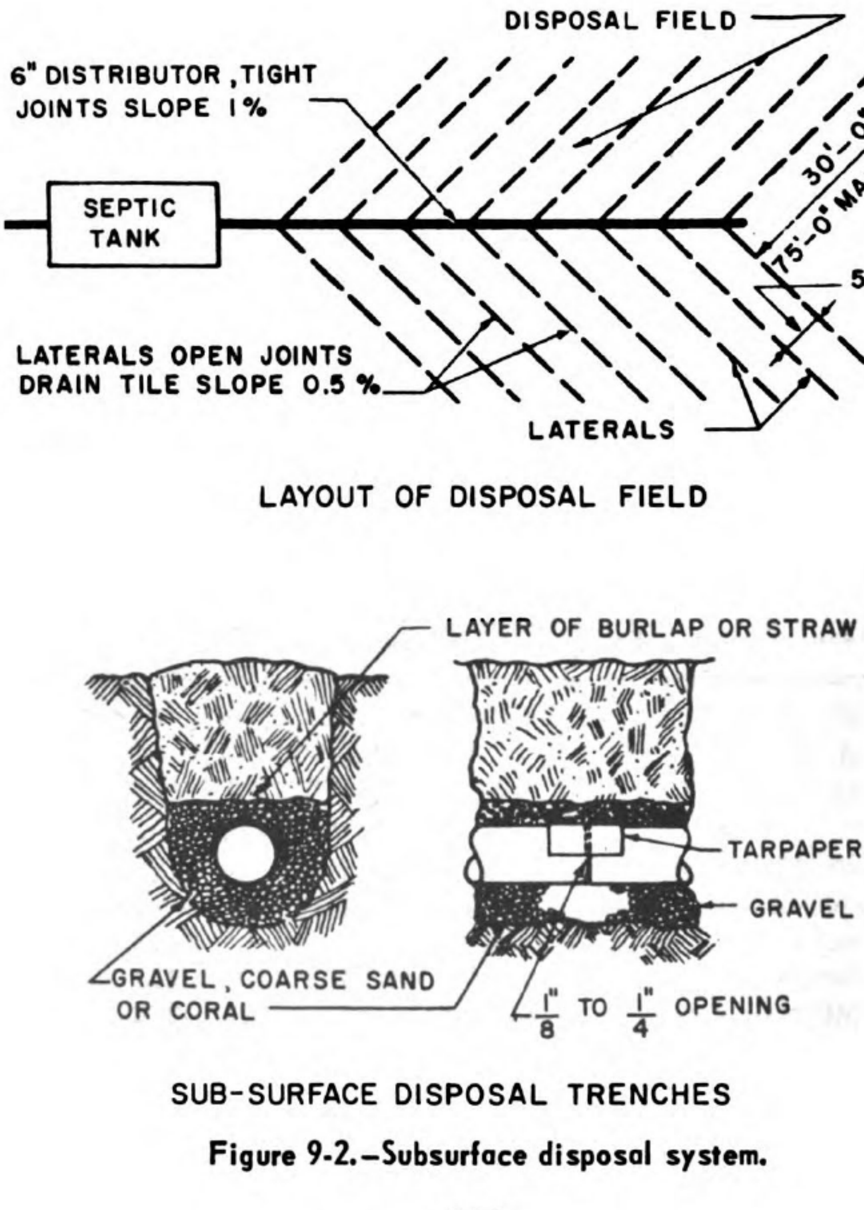


Figure 9-2.—Subsurface disposal system.

construction of a subsurface system. Since bacterial decomposition of organic matter becomes less as the depth of the pit increases, never extend a subsurface tile system more than 2 ft below ground level.

The main distributing sewers are generally made of 6-in. tile, laid on a slope of about 1 percent gradient to ensure that the sewage will have a velocity of about 2 ft per second. The joints must be tight. Laterals feeding to the manifold or main sewers should not exceed 100 ft in length, and will require a gradient of about 1/2 percent; the joints are from 1/8 to 1/4 in. wide, and are open except for strips of burlap or tar paper over their upper circumference. The trenches for laterals are usually from 1 to 3 ft wide; their depth may be from 1 to 2 ft, depending upon surface contour and depth of soil, and they should be spaced from 5 to 10 ft apart, depending upon soil porosity.

In constructing the trenches, place the tile at the bottom, then lay down a bed of broken stone, gravel, or coral. This bed should be the full width of the trench, and about 1 ft deep, and should be covered with burlap, straw, or leaves. The trench is then backfilled.

A subsurface tile system will prove more practical if the disposal field can be divided into two sections. By alternating the use of these sections at regular intervals, better disposal is ensured.

Sand Filters and Evaporation Beds

In areas where the soil is too impervious to readily absorb liquid waste, or where the water table is fairly close to the ground surface, subsurface sand filters and evaporation beds can be constructed, as appropriate. The former are practicable where the water table is high; the latter are best used only where the climate is hot and dry.

A subsurface sand filter is constructed as indicated in figure 9-3. A trench or series of trenches, with a bottom layer of crushed stone or gravel, and with 12 to 18 in. of coarse sand superimposed, forms the underdrain. One pipeline is run through the gravel, and a second pipeline is run through the upper layer of the sand. Liquid waste enters through the upper piping system; the sand layer

serves as a filtering medium; and the clean drainage is conveyed to a drainage channel through the lower piping system.

To construct an evaporation bed, scrape off the top soil to level the area, and then build an earthen dike from 10 to 15 in. high. Corrugate the bed by raking it into a series of ridges. For kitchen waste, allow about 3 sq ft per person; be sure to pass this waste through a grease trap before running it onto the evaporation bed. Allow 2 sq ft per person for bath waste.

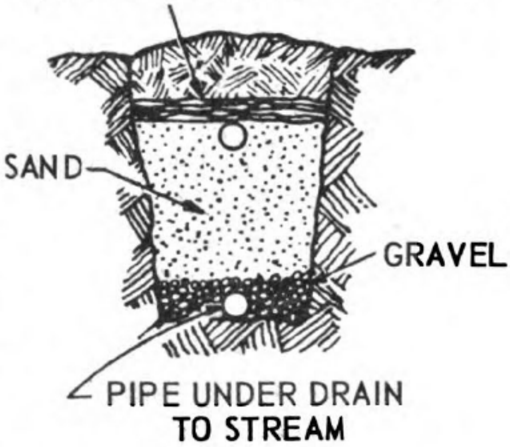


Figure 9-3.—Subsurface sand filter construction.

Deposit the sludge in fairly small increments, and to only one bed at a time. Do not deposit additional sludge until the dried sludge cake from the previous deposit has been removed from the bed. In general, keep the depth of a deposit down to 10 inches.

Arrange the beds so that the waste will be directed fairly evenly to all parts. Have a sufficient area so that some of the beds can be spared from service, for drying and respading.

In systems where digested sludge is delivered to drying beds via pipelines, the delivery lines must be drained in winter, to prevent the sludge freezing in the pipe. The lines should be drained in summer as well, since pipes that contain confined sludge and that are exposed to the sun may explode from the pressure of gases generated in the sludge by the sun's heat.

Dilution

At overseas bases especially, it may be necessary to dispose of sewage by the dilution process. Make sure that the body of water is large enough to serve this purpose. Otherwise, the water will become loaded with

organic matter, and the available oxygen will be consumed, and the water will become septic and malodorous.

When waste is deposited in a body of water, the bacterial activity in the waste matter utilizes the oxygen dissolved in the water to stabilize organic substance. To ensure safe concentration of dissolved oxygen in the receiving body of water, observe carefully the following ratios of waste liquid to fresh water:

1. One part raw sewage should be mixed with at least 100 parts of fresh water.

2. One part of settled sewage should be mixed with at least 70 parts of water.

3. One part of filtered sewage should be mixed with at least 10 parts of fresh water.

The sewage outfall must not be located in the vicinity of water intakes, bathing facilities, or shellfish beds. Indeed, where such facilities are present in the receiving body of water, it may become a necessary health protection to arrange for complete treatment of the waste, and even to follow this with disinfection with chlorine.

Waste outlets into a river should be so located that the current will cause rapid dispersion of the waste matter. If the outfall sewer is into a lake or the ocean, the point of discharge should be into deep water, where prevailing currents will not bring polluted water back to shore.

Secondary Treatment Processes

Secondary treatment given to sewage consists in some treatment in addition to sedimentation. Disposal fields and seepage pits are secondary treatment devices, but they require favorable conditions of soil, topography, and climate, and even under favorable conditions, the volume of sewage that can be disposed of is relatively small. When secondary treatment must be given to the sewage of more than a few hundred persons, one of the municipal type biological processes should be employed, and the treated sewage should then be disposed of by dilution.

The important municipal type processes can be grouped under the term "oxidation process," which involves the breaking down of organic solids into stable compounds, through biological activity in the presence of oxygen. The purpose of an oxidation process is, of

course, to reduce the pollution load imposed on the natural bodies of water into which the sewage is discharged. The method by which the oxidation is accomplished is the concentration, in tanks or filters, of the natural aerobic biological processes which purify and destroy waste material in streams and lakes.

The three most important secondary treatment processes are: (1) trickling filter process, (2) activated sludge process, and (3) sand filtration. The following brief discussion of these three processes should give you all the information you will need for putting them to practical use. However, there can be many variations in equipment design and operation, as you will appreciate if you study technical data dealing with sewage treatment.

TRICKLING FILTERS consist of beds of coarse stones, 6 to 10 ft deep, over which the sewage is intermittently applied through spray nozzles or rotating distributor arms. The practical limits for the size of these stones is from 1 to 2-1/2 in. Smaller stones would provide a greater surface area for oxidation, but would also increase the likelihood of clogging.

As the bacteria cell membranes absorb water, they swell; a mass or colony of bacteria embedded in a jelly-like substance thus forms. As the sewage trickles down over this zoogloeic film on the surface of the stones, organic matter is removed. Every six months or so, the accumulated organic slime will normally break loose and discharge. During this unloading period, the filter effluent will be highly charged with suspended solids, which must be removed in secondary settling tanks provided for this purpose.

The standard rate for dosing trickling filters is from 2 to 4 million gallons per acre per day. Recent developments have resulted in trickling filters that can be dosed at a rate of from 15 to 30 million gpd per acre. However, these filters require the use of some type of device for recirculating the effluent through the filter. All in all, the standard rate trickling filter will prove the simplest and most reliable device for secondary treatment of sewage.

The overall efficiency of sewage plants equipped with these lower rate trickling filters is from 70 to 90 percent removal of suspended solids, and from 90 to 95 percent

removal of bacteria. The reduction in biochemical oxygen demand is usually from 75 to 90 percent. Additional reduction can be effected by chlorination; the use of chlorine or of chlorine compounds will also serve to kill many of the remaining bacteria, and will reduce some of the odor from stale sewage.

ACTIVATED SLUDGE in which a growth of aerobic bacteria has developed performs the same function as the zoogloeic film on the stones of a trickling filter. A continual supply of oxygen must be present. The organisms contained in the sludge feed upon the organic matter in the aerated sewage.

Since the sludge grows with aeration, an excess over the process requirements appears in the final tanks. Some of this is returned and mixed with incoming sewage, since activated sludge must be present in order to ensure proper purification. The remainder of the excess sludge is usually returned to the sewage ahead of the preliminary clarifiers, and is removed in the primary sedimentation tank and disposed of with the other primary sludge.

Operating at average performance, an activated sludge plant will usually produce a clear and practically odorless effluent, and its efficiency may be as high as 90 percent removal of suspended solids and bacteria. The clear effluent, however, sometimes gives an overly favorable impression of plant performance. While initial cost of the activated sludge plant is less than that of a trickling filter plant, operating costs are much higher, and the process requires expert control.

The SAND FILTER is an underdrained sand bed upon which the sewage is flooded, as rapidly as possible, in 1 to 4 intermittent doses. Time must then be allowed for the sewage to filter through the bed, and for the bed to aerate, before the next dose is applied.

Capacity of a sand filter is 30,000 gallons or more of raw sewage, or 100,000 gallons of completely treated sewage, per acre per day. Three or more filter beds will be needed if the proper schedule of rotation is to be obtained. Raking or harrowing the sand surface helps in maintaining a fairly rapid filter rate. When raking no longer proves effective, the upper layer of sand can be removed.

These intermittent sand filters produce a high degree of treatment, and if natural sand beds are conveniently located these filters can readily be improvised with the use of tile or concrete sewer pipe. The principal disadvantages of this method of treatment are the large areas required, and the difficulty of controlling the emanation of odors.

Chlorination

Where a sewage outfall is located close to a bathing beach, shellfish beds, or water supply, it may be necessary to provide additional disinfection for the treated effluent. This necessity arises from the fact that secondary treatment processes will not eliminate all the disease-causing organisms from the sewage. When disinfection is required, it is accomplished by the use of chlorine or of chlorine compounds.

The character of sewage effluent is subject to wide variations, and good results will usually depend upon frequent adjustments of the chlorine doses. Therefore, no hard and fast dosage requirements can be given. However, the following ranges will serve as a practical guide: for trickling filter effluents, use a dose of from 3 to 15 ppm (parts per million); for Imhoff tank effluents, use from 5 to 20 ppm; and for septic tank effluents, use from 10 to 25 ppm. In any case, you should have at least 0.5 ppm of residual chlorine after a 15-minute contact period, to ensure effective disinfection.

Chlorine can be used in the treatment plants, to reduce objectionable odors. The chlorination of partially or completely treated sewage in dry, hot weather will retard decomposition in the receiving stream until the sewage has been widely dispersed.

Sludge Disposal

The sludge that collects in the sedimentation tanks of a sewage plant may be disposed of as waste material, or it may be utilized to heat digestion tanks.

In plants having mechanically cleaned settling tanks, the sludge is usually subject to anaerobic digestion. During this digestion, methane gas is produced and the

organic solids are changed into humus-like material, which can be disposed of by burning or dumping.

Since the gas released by sludge is similar to natural gas, it can be used to heat digestion tanks, to operate gas engines, or to provide general heating. Sludge gas is produced at the rate of about 1 cu ft per day per person contributing sewage, and has a fuel value of about 650 Btu per cu ft.

The effluent from secondary treatment processes can be clarified and used to irrigate plantings. However, if this effluent has a high chloride content, its use may be damaging to grass and shrubs.

The problems connected with sewage systems and sewage disposal will depend upon the type of Navy installation, and its location. In densely habited areas, the existing facilities will probably be sufficient to meet any situation; in forward areas, along a line of march or at a site to be occupied only for a brief time, emergency measures will probably suffice. In between these extremes there will be a wide variety of problems that will tax the ingenuity and the ability of the personnel responsible for the installation, operation, and maintenance of a safe and adequate sewage system.

The sewage plant operator should assemble, for ready reference, as much printed material on equipment and operation as is available, or as can readily be obtained. The following publications, assembled in a binder for ready reference, will be of particular help to the Utilities Man.

1. *Mechanical Sludge Collectors,* published by the American Well Company.

2. *Sludge Pump,* published by R. B. Carter Company.

3. *Gas and Coal Fired Boilers and Auxiliary Equipment,* published by the American Radiator and Standard Sanitary Company, and H. B. Smith Company.

4. *Safety Gas Equipment,* published by the Vapor Recovery System Company.

5. *Chlorinator,* published by the Wallace and Tiernan Company.

6. *Floating Covers,* published by the Pacific Flush Tank Company.

EXPLOSION HAZARDS IN SEWAGE GASES

The possibility of explosions is always present in sewage treatment plants, since a mixture of sewage gas and air, in certain proportions, is an explosive mixture. The proportions vary according to the gases involved, but even very low percentages of gas in a gas-air mixture can prove explosive.

There are two main sources of potentially dangerous sewer gas: leakage from the sewer system, and decomposition of sewage solids in digestion tanks.

Strict application of the five safety rules listed here will help prevent explosions. The slightest infractions of these rules may result in death or injury to personnel and extensive damage to the equipment and structures.

1. Do not smoke, drop lighted matches, or use open flames in or around sewers, screen chambers, sludge digestors, and settling tanks.

2. Check periodically for gas leaks in piping joints, gas valve stems, condensate-trap ports or valves, gas-meter connections, gas-pressure regulators, and the like. To test for leaks, spread a soap solution over joints, stems, and other possible openings and watch for gas bubbles.

3. With an explosimeter, test all enclosed spaces for the presence of explosive gases.

4. Before personnel are allowed to enter sewers, manholes, pits, or enclosed tanks, test for toxic or explosive gases and for oxygen deficiency. Never allow any one to work alone in an enclosed space without taking all possible safety precautions, including a line around his chest and a man in the clear to haul him out if necessary.

5. When filling and emptying a digester tank, prevent the formation of an explosive air-methane gas mixture under the tank cover by using forced ventilation to remove the gas. Continue ventilation until the work is completed.

REFUSE DISPOSAL

In addition to the waste products disposed of by sewage systems, all installations will have refuse such as tins, grease, bones, and other garbage. Disposal of station

rubbish and garbage should be accomplished by the most economical method appropriate to the conditions and problems existing at the specific installation.

For health and safety of personnel, and for general orderliness around an activity, all waste should be removed and disposed of daily. At an established base, responsibility for this disposal rests with the public works officer, who is responsible to the commanding officer; at a nonpermanent base, where a construction battalion is operating, an officer designated by the commanding officer will be responsible. However, the Utilities Man should understand the reasons for adequate disposal procedures, and the hazards involved in various forms of waste, if he is to properly discharge his own responsibilities in this connection.

In general, the refuse that must be disposed of will consist of garbage, rubbish (both combustible and noncombustible), ashes, and such liquid and semiliquid combustible wastes as petroleum sludge, crankcase oils, greases, tars, and refuse oil from the bilges of ships.

The establishment of an adequate system of depositing, collecting, and disposing of wastes involves the consideration of 4 major factors:

1. What are the requirements of the installation in terms of the kind and amount of waste that must be disposed of? (In determining these requirements, it is not necessary to include dehydrated sewage sludge, excavated earth, oil sludge, or discarded explosives. Other provisions are made for the disposal of such refuse.)
2. What type design and what capacity of equipment is necessary?
3. How shall the disposal facilities be constructed?
4. What maintenance will be necessary?

Where liquid or semiliquid combustible wastes occur, special care must be exercised. If feasible, salvage these waste products for use as road-conditioning materials. Occasionally, this type of refuse can be dumped on waste land, but care must be taken to guard against contamination of the water supply, or seepage to the waterfront.

If it is necessary to burn this type of refuse, it should be burned in open pits. Only under special conditions should it be burned in an incinerator. Needless to say,

all fire regulations must be scrupulously followed in the handling and disposing of these combustion wastes.

Fire hazards not only exist where there are liquid and semiliquid combustible wastes, but also where there is an accumulation of dry rubbish, especially if it is piled in an unventilated corner.

Disposal by Sale

Garbage can often be sold to civilians as hog feed or for use as fertilizer. The quantity available will be a factor in deciding whether or not the refuse is salable; if it is sold under contract, the terms of the contract will determine the extent to which the various kinds of refuse must be segregated. Tins must be separated from regular garbage; sometimes it is possible to bale and sell the tins.

The regular garbage must also be separated, to segregate coffee and tea grounds, eggshells, corn husks, citrus fruit rinds, and so forth. This type of refuse can be used as fertilizer, if it is turned under promptly. The remainder of the garbage may be sold "as is," or it may be segregated into grease, fat, bones, and hogfood garbage and sold separately.

Delays in disposal, spilling in transfer, or lack of cleanliness can lead to unsanitary and objectionable conditions about the installation. The cans, therefore, should be emptied and cleaned daily. Garbage trucks also should be cleaned daily, and rubbish trucks and containers as often as seems necessary.

Burial

When a unit is on the march, it is probably best to bury garbage. A trench or pit about 3 ft deep should be dug to receive the refuse; when it is filled to within 2 ft of the ground surface, the trench should be covered with well-packed dirt. Each day's accumulation of garbage should be sprayed with oil, to control the breeding of flies, and the trench should be sprayed again before it is dirt-packed. Sweepings, ashes, and flattened cans may be disposed of on the ground surface.

Where the campsite is to be occupied for a fairly long period of time, and where there is suitable ground

available, the garbage and rubbish can be buried in sanitary fills. This method is both practical and economical, especially at an activity comprising 1,000 or more men; it will be especially desirable if the campsite includes low-lying areas that would be reclaimable by filling.

The sanitary fill method of burying waste comprises 4 operations: excavating the trench, filling in the refuse, covering with earth, and final compacting. The soil must be of a type that can readily be excavated, and when it is used as a covering it should provide a homogeneous mass that prevents the escape of odors, and that is not favorable to the existence of rodents and flies.

The amount of land allowable for a sanitary fill should be in the proportion of from 1 to 1-1/2 acre-feet per year for each 1,000 men. Depth of fill will depend upon the type of terrain and the size of the installation. No fill, however, should be less than 1 ft deep, and most of them will range from 3 to 6 ft in depth.

The terrain must permit good drainage, with no danger of pollution of surface or subsurface water supply. While it would seem desirable to use a natural ravine, there is the risk that the refuse might be washed out by storm waters. If possible, the site should be located so that prevailing winds will carry any odors away from habitations and highways. The distance from highways and from human activities must be at least 500 ft, but the area left vacant must be accessible to the equipment to be used in excavating, filling and compacting.

Disposal at Sea

The most feasible method of disposing of garbage may seem to be dumping it at sea; however, this must never be done unless there is no danger of polluting adjacent shores, or of having some of the refuse returned in a backwash of the waters.

To avoid pollution of waters used by other activities, or settlements, never dump garbage into streams or tidal waters near or above established communities. Always adhere to local regulations, and if necessary, obtain the approval of sanitary authorities on adjacent shores.

To avoid pollution of your own shore waters, and the depositing of trash on your beaches, observe the winds

and the currents around your base. Then carry your garbage far enough offshore so that none of it will be washed back. Time your dumping schedule to the tide, so that the refuse will be carried completely and permanently away from the area.

If close offshore disposal is not satisfactory, the waste material can be carried by barge to the required distance. A barge must be especially assigned for this service, and both the barge and the loading station at the dock must be maintained in a sanitary condition. If the garbage is to be sunk in metal drums or containers these must be perforated or flattened, to ensure that they will sink.

Incineration

Solid refuse will usually comprise an admixture of organic combustibles and inorganic noncombustibles. Since station incinerators are intended for burning combustible refuse, the inorganic incombustibles (ashes, metal, broken glass or crockery) should be segregated, if possible. However, an incineration plant is capable of accommodating some small amount of incombustible material.

If garbage is the only solid refuse to be burned, it will ordinarily be best to dispose of it in a sanitary fill, or perhaps to grind it and dispose of it via the sewage system. The use of an incinerator for garbage only is not economical. Some analysis, therefore, should be made of the mixture to be burned. The percentage of moisture, and of inert material, are important factors in the heat value of the refuse itself, and the heat value of the refuse, in conjunction with the method of firing the furnace, will determine whether a supplementary amount of fuel must be used to consume a specific lot of waste.

The combined garbage and rubbish incinerator of the type in general use at Navy installations has a single overhead chute, through which rubbish and wet garbage are deposited. The admixture lands upon a drying hearth, and combustion gases from the burning grates pass directly over this hearth, evaporating the moisture and igniting the dry combustibles.

CONSTRUCTION of a typical incinerator is illustrated in figure 9-4. Note the chute through which the refuse is dropped upon the inclined hearth, and the ignition chamber directly above the grates and the hearth. Component parts are furnace, stack (or chimney), storage spaces, and any auxiliary equipment needed for controlling combustion.

The furnace includes a chamber lined with firebrick, the grates, the drying hearth, the ash pit, and the chambers for ignition, mixing, and combustion. The furnace ceiling is an arched, self-supporting structure. The grates are bars of cast iron, upon which dry refuse or solid fuel is placed for burning. The drying hearth is an inclined deck just above and forward of the grates, and provides a surface upon which the wet garbage can be spread. The effective grate surface is the grate area plus that portion of the hearth area that is serviceable as grate surface.

The ignition chamber is connected with the combustion chamber by a space or a passage known as the mixing chamber. A flue leads from the combustion chamber to the stack. An adjustable gate, or damper, in the flue can be used to restrict the flow of combustion gases. The baffle at the forward end of the ignition chamber is called the bridge wall.

CAPACITY of an incinerator is determined by 2 factors: (1) weight and nature of the waste taken over a number of days, and averaged for a 24-hour period; and (2) the ability of the furnace to dispose of this average amount within 8 hours. Additional loads are taken care of by overtime operation of the incinerator. It is advisable to allow a 25-percent margin to compensate for possible variation in amount or composition of the refuse. Under ordinary circumstances, there will be a period every day when the incinerator is not in operation, and cleaning and maintenance work are performed during this idle period.

OPERATION of the furnace should be preceded by a warming-up process in which small quantities of rubbish are burned on the grate in order to warm up the walls of the combustion chamber. The garbage and rubbish to be burned should be available, and surveyed to determine if the fuel value of the mixture is sufficient for complete combustion.

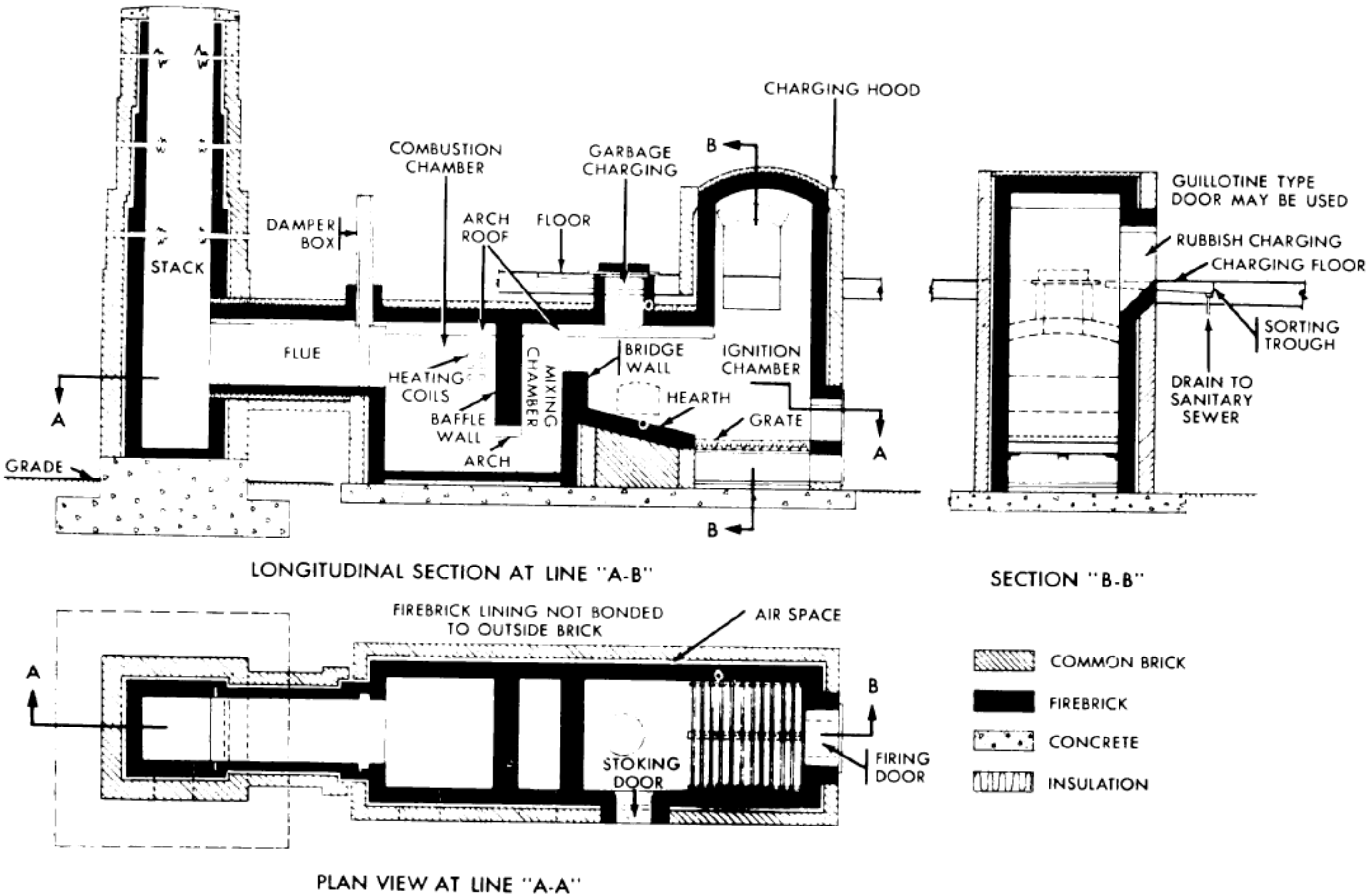


Figure 9-4.—Diagram of a typical incinerator.

A mixture composed of 3/5 garbage, with a moisture content of 75 percent, and the other 2/5 rubbish, with about 15 percent inert material including moisture, will have a heat value of approximately 3,000 Btu per lb. If the proportion of garbage is larger than this, supplementary fuel will be required.

The firing tools required are a slice bar, a 2-pronged stoking hoe, an ash hoe, a long-handled shovel, and two 6-tine manure forks. The stoking tool must be used with care, to avoid damage to the brickwork; it is advisable to do no more stoking than is absolutely necessary.

When the warming of the cold furnace has continued to the point where the combustion chamber walls, observed through the inspection port, appear to emit a light glow, the charging of the garbage and rubbish can be started.

A small amount of the refuse material should be deposited through the charging chute, and spread (through the stoking door) upon the drying hearth. This charge should be built up gradually until it reaches a depth of from 6 to 8 in., but no material should be allowed to spill over the bridge wall. The slice bar is used to lift and spread this material on the hearth, so as to facilitate moisture evaporation and heating. The stoking hoe can be used to draw the material toward the grates. When the furnace is in full operation, the rubbish charges should be as large as practicable.

The damper should be regulated to prevent excessive draft. A high velocity draft could carry refuse into the flue and the stack, as well as cool the furnace. To avoid excessive amounts of air entering the furnace, guard against any unnecessary opening of the firing, stoking, or charging doors.

Good operation involves care in charging, so as not to put wet material directly upon hot refractory surfaces, nor to overload the furnace. It involves regulating the combustion air so that there will be no fluctuation of furnace temperature. It involves discontinuing the use of auxiliary fuel as soon as the heat value from the waste material is sufficient to maintain complete combustion.

MAINTENANCE PROCEDURES regularly carried out will tend to prolong the life of an incinerator. Periodic inspections should be made of the furnace interior, to

observe any deterioration of the brickwork. The exterior should be checked for cracks in wall surfaces or around openings. The draft gage should be inspected for possible air leaks through the setting.

Minor repairs can be made with plastic refractory material, when inspection reveals spalling, cracks, or loosened bricks.

When the furnace is idle, the areas above and below the grates should be brushed down to remove ashes, soot, and any remaining trash. The hot water heating unit, the draft gage opening, and the thermocouple connections can be inspected at this time. Less frequently, an inspection should be made of the flue and the chimney.

Precautions

The disposal of waste around a Navy installation calls for the exercise of certain precautions. Liquid waste, for example, must never be disposed of in such a way that it might drain into water supply sources. Combustible wastes must be burned in pits; and because of fire hazards, they should never be allowed to accumulate.

Garbage, on the other hand, should never be burned in an open pit, because of the smoke, odors, and ever-present possibility of breeding flies or other pests. As mentioned before, amounts of garbage too small to justify the use of an incinerator should be buried in a sanitary fill; if this procedure is not feasible, small amounts of garbage can be ground and fed to the sewage system.

Dry rubbish should be deposited in fireproof containers, and emptied daily. Such waste might easily be ignited by sparks or smouldering cigarettes, and there is always the risk of spontaneous combustion. Especially, this type of rubbish should never be allowed to accumulate in a corner, or other unventilated space.

Waste that is to be burned in an incinerator should never include fats, greases, flammable liquids, or explosives.

Personnel who must collect and handle refuse should be trained to wear protective clothing as required, and to see that loading equipment and tools are properly secured to the collection trucks.

PEST CONTROL

Measures for the control of insects, rodents, and other pests are given high priority at Navy installations. The possibility of loss of life from rodent- or insect-borne diseases, the reduction of efficient man-hours of work, and the damage that can be done to structures and to stored supplies, make it imperative that an effective and continuing program against pests be maintained.

In terms of possible economic damage to buildings, equipment, and materials, as well as the menace to health and sanitation, there are many pests: mosquitoes, bedbugs, fleas, termites, ants, borers, cockroaches, rats and so forth. Providing the needed controls demands the use of trained personnel. Among these trained personnel is the Utilities Man, who normally will operate and maintain the equipment used to combat these pests. He should know, therefore, the measures that can be taken against the various types of pests. He should also know the general line of responsibility, so that he may better see where his duties fit into the picture.

The maintenance and operation of an adequate program of pest control at an installation is the responsibility of the commanding officer, who can delegate certain phases of this work, as appropriate, to the medical and the public works departments.

Normally, the area in which the medical department will function is as follows:

1. Conducting surveys of disease vectors.
2. Identification of species and sources of pests that affect health or sanitation.
3. Planning the control operations.
4. Delineating the measures to be taken for personnel protection.
5. Ensuring that toxic pesticides are used safely, and in accordance with pertinent regulations.

The Public Works Department is normally responsible for the area of economic pests, and supports the Medical Department in the control of disease vectors. Their responsibilities are as follows:

1. Providing trained personnel for control operations.

2. Inspections and surveys of economic pest problems, and of disease vector problems as requested by and in cooperation with the Medical Department.

3. Maintenance of some type of training program, to keep supervisory personnel aware of new techniques and developments.

Both the Medical and Public Works Departments are expected to coordinate their pest control programs with those of the local communities, and of other civilian and government agencies.

Mention has already been made, at the beginning of this chapter, of the comprehensive and helpful technical manual, entitled *Insect and Rodent Control.* This reference is an excellent text for any Utilities Man whose duty assignment is at an installation where the nature of the terrain provides favorable spots where insects or rodents may breed.

Mosquito Control

The elimination of mosquitoes is an important factor at military installations, since the presence of these insects in numbers can cause a serious impairment of normal activities. At the very least, the mosquito is a pest that can reduce the efficiency of the men. Furthermore, it is frequently a disease carrier, transmitting such diseases as malaria, yellow fever, dengue, and encephalitis. The eggs, or larvae, are laid on water surfaces, or on soil subject to flooding, and feed upon organic matter in the water. Shallow, sluggish streams and ponds, with plant growth, provide ideal conditions for the breeding of mosquitoes.

METHODS for controlling this type of pest may be of a temporary or a permanent nature, depending upon local conditions. Permanent methods are designed to eliminate or to control the water areas in which mosquitoes breed. Drainage of the marshy places would seem to be the obvious method, but it may be an expensive one. However, if the general level of the marshy area is the same as or below that of an adjacent body of water, drainage by pumping will probably be the best solution.

In places where the construction of small dams is feasible, it will be possible to release the collected

waters periodically, and thus flush the stream below the dam. In coastal marshes, altering the salt content of the sluggish water by permitting sea water to enter will limit the breeding of some species. For other species, excluding sea water, and thus limiting the salt content, will be more effective.

Control of aquatic vegetation which provides shelter or protection for larvae is another method of mosquito control. The vegetation may be removed by mechanical means, or treated with a chemical, depending upon the type of vegetation, size of area, and utilization of the water.

Shallow pools, and depressions in which storm waters collect, can be filled and graded. Seepage areas can be drained by ditches.

The most practicable methods of controlling adult mosquitoes are the screening of occupied structures, and the frequent use of space sprays. Where persistent reentry of the mosquitoes is to be expected, a residual spray containing 5% DDT is used. The DDT is left on the sprayed surface as a residual deposit, and contact with this dry deposit kills the insect. Such a spray will be effective for a 5-week period, or longer. Personnel using a residual spray, however, must have respirators and protective clothing, and must be careful to observe all fire prevention regulations. Because of the greater concentration of toxic material in a residual spray, it must never be used as a space spray.

INDIVIDUAL PROTECTION is necessary in the earlier phases of an occupation, before control operations are established. It is also advised as a supplementary measure of a control program in heavily infested areas. The more common methods for individual protection are the use of insect repellents, of bed nets, and of protective clothing.

Repellents applied to the body will be effective for a period of about 3 or 4 hours. The heaviest application should be made about the ankles.

Bed nets should be used in areas infested with disease-carrying mosquitoes, even though the barracks are screened. The nets should be inspected daily, and holes should be repaired promptly. About every 2 or 3 months, the nets should be treated with DDT.

If head nets, gloves, and leggings are available, personnel should wear them during their daily activities. In malarious districts, long sleeves and trousers over the ankles should be required uniform from an hour before sundown to an hour after sunup.

AREA CONTROL is best accomplished by locating an installation beyond mosquito flight range from concentrated breeding places. Military considerations may not permit of this precaution, however, and in such cases careful thought must be given to providing personnel quarters sufficiently comfortable so that the men will tend to remain indoors when not actively employed on duty assignments.

Buildings should be provided with good ventilation, and all doors, windows, and ventilating spaces should be screened. The screening should be periodically inspected, and promptly repaired when necessary. Every month during the mosquito season, the screens should be treated with a 5-percent solution of DDT.

Buildings should be constructed so that screen doors are located on the windward side, and open outward. The reason for this is that insects tend to congregate on the leeward side of any windbreak.

Flies

The common house fly, the stable fly, and the blow fly (greenbottle and bluebottle) will often prove annoying pests at a military installation. The primary sanitation method, in combatting these pests, is to promptly eliminate all fermenting and decaying organic matter, garbage, and animal and human excrement. Screens on buildings, and the use of space sprays, are methods of controlling flies as well as mosquitoes.

If fly baits are used, they must be either sugar-malathion or cornmeal-malathion bait. The malathion insecticide concentrates are toxic to humans, and care should be taken to prevent inhalation or prolonged contact. Wear rubber gloves during the preparation and distribution of the bait, and wash carefully after you have finished using it.

Other Insects

Rat mites, chiggers, poisonous spiders, ticks, bedbugs, and body lice are some of the other insect pests that may have to be controlled or eliminated. Most of these are disease carriers, and can be a menace to the health of personnel at an installation; all of them are a menace to personnel comfort and efficiency. Means for combatting these various pests can be found in *Insect and Rodent Control,* already mentioned.

Rodents

Satisfactory rat control involves the removal of the food supply upon which they feed, the ratproofing of buildings and elimination of rat harborages, and the destruction of the rats themselves. Prompt disposal of garbage, in accordance with the instructions already given in this chapter, in the section, Refuse Disposal, is the primary step. Proper handling and protection of food supplies is also important; it is advisable to place storaged food supplies at least 2 ft away from walls, so that there will be minimum cover and concealment for rodents.

Ratproofing of buildings is a project that must be coordinated with the construction, alteration, and maintenance of these structures. Spaces between walls and double floors should be blocked to prevent rat runways; conduits for wiring should be limited to sizes that will not permit rat passage. Foundations should extend at least 3 ft below ground level, and there should be offsets to prevent burrowing beneath the walls.

If inspection shows evidence of gnawing around wood sills and doors, a sheet metal sheathing should be applied. Openings greater than 1/2 in. wide in the exterior of buildings should be closed with hardware cloth, cement, or similar rat-proofing material. Cracks around doorways, gratings, and windows within 4 ft of ground level should also be ratproofed.

Fumigation of rat burrows should be conducted only by personnel trained in the use of calcium cyanide powder. When this toxic dust has been injected into the burrows, the entrances and exits can be tamped with earth.

Rat poisons (rodenticides) can be utilized to kill the rats without the necessity of locating their burrows. Again, this must be done by properly trained and supervised personnel, since most of the rodenticides are toxic to man and to domestic animals.

Rat traps should not be relied upon as a single means of rat control, but they are useful as supplementary measures. The baited traps should be placed along protected runways. The bait to be used will vary, since the food preferred by rats will vary with species, and with geographical area. The traps should be inspected regularly, the trapped rodents removed, and the dried or unattractive bait replaced.

Training and Safety

Training courses for the personnel who undertake the various types of pest control are an absolute necessity, because of the toxicity of the solvents that are used. Supplementary on-the-job training at the installation is also advisable.

Protective clothing must be worn, and protective devices such as respirators and airline masks are also necessary. Approved methods of storage and transportation must be followed. When basic precautions are taken, no adverse effects will normally result, either to the control operations personnel, or to the personnel within the treated environment.

When assisting in a control or elimination program, the Utilities Man should be careful to avoid inhaling any of the toxic material, or contaminating his mouth, eyes, or skin. He should not smoke while mixing, handling, or applying pesticides, nor use solutions in the presence of open flame. He should use the required protective devices and clothing. If nausea or vomiting occurs, or if he suffers loss of appetite, he should report to sick bay.

SUPERVISING AND TRAINING PERSONNEL

The Utilities Man, as key man in the operation and maintenance of equipment used in waste disposal and pest control, has a heavy responsibility. This will be especially true at advanced bases, where primitive conditions

may add to the problems to be solved, and the necessary economical use of manpower may result in new and unfamiliar duties for all personnel.

To safeguard the health of the base, it is imperative that everyone engaged in this type of work have the necessary knowledge and training. Therefore, you must not only be ready to accomplish your own tasks, but must also be able to train and supervise Utilities Men second class and third class, so that they, too, may learn to perform the work in a satisfactory manner.

QUIZ

1. Who is normally the key person in the operation of equipment for pest control at a Navy installation?
   (a) The medical officer
   (b) The public works officer
   (c) The Utilities Man 1 or C
   (d) The local health or sanitation officer
2. What is recommended as a method of flushing latrine channels at a temporary base?
3. After water pollution, what is the chief thing to guard against in the construction of latrines?
4. A latrine pit should be sprayed, filled in, and mounded over when it has been filled to within
   (a) 24 inches of ground surface
   (b) 18 inches of ground surface
   (c) 12 inches of ground surface
   (d) 6 inches of ground surface
5. What can be used to make cracks in a latrine box fly-tight?
6. Urine soakage pits or trenches should be surfaced with
   (a) broken stone, brick, and other impervious rubble
   (b) wire mesh
   (c) tar paper
   (d) oil-soaked burlap and earth
7. What are the 2 disadvantages, mentioned in the text, of chemical toilets?
8. The tanks of chemical toilets should be emptied by which of the following methods?
   (a) Gravity drains
   (b) Pumping
   (c) Bailing
   (d) Drains to septic tanks

9. What is the most sanitary method of removing liquid wastes from the vicinity of habited areas?
10. Where the soil is pervious, and the amount of liquid waste small, what is the method suggested in the text for disposing of the waste?
11. How much cover is advisable for the pipes of a sewage system, to ensure protection against traffic and frost?
12. For sewers consisting of pipes 8 inches in diameter, manholes should be provided at intervals of at least
    (a) 600 ft
    (b) 500 ft
    (c) 400 ft
    (d) 300 ft
13. What does an excessively diluted flow in a sewer usually indicate?
14. Why must the flow of sewage through a settling tank be held at a low velocity?
15. What are the two disadvantages of septic tanks, as indicated in the text.
16. What is the recommended procedure for disposing of the effluent from a combined settling and digestion tank?
17. A subsurface tile system should never extend more than 2 ft below ground surface because the
    (a) cost of construction is too high for the results obtained
    (b) waste will seep into and pollute the water table
    (c) rate of absorption through open joints will decrease as depth of pit increases
    (d) rate of bacterial decomposition of organic matter will decrease as depth of pit increases
18. In what type of climate is the use of evaporation beds most practicable?
19. What are the recommended proportions of sewage and water for raw sewage? Settled sewage? Filtered sewage?
20. When an outfall sewer is into the ocean, why must the point of discharge be located in deep water?
21. Secondary treatment given to sewage consists in some treatment in addition to
    (a) sedimentation
    (b) oxidation
    (c) filtration
    (d) chlorination
22. What are the 3 most important secondary treatment processes?

23. What is the treatment process in which sewage is intermittently applied, through spray nozzles or rotating arms, over a bed of coarse stones?
24. For what reason would you chlorinate completely treated sewage in a receiving stream, in hot, dry weather?
25. The sludge gas produced in mechanically cleaned settling tanks may have a fuel value as high as
    (a) 2400 Btu per cu ft
    (b) 1850 Btu per cu ft
    (c) 1200 Btu per cu ft
    (d) 650 Btu per cu ft
26. What are the 2 main sources of potentially explosive sewer gas in a sewage treatment plant?
27. To ensure health, good sanitation, and general good order, how often should the waste around an activity be removed and disposed of?
28. Liquid or semiliquid combustible waste products can sometimes be utilized for what practical purpose?
29. At an activity comprising 1,000 men at a semipermanent campsite, the best method of disposing of garbage will probably be to
    (a) burn it in an open pit
    (b) bury it in a sanitary fill
    (c) grind it and feed it to the sewage system
    (d) barge it to sea for dumping
30. What 2 factors must be considered before a decision is made to dispose of garbage by dumping it at sea?
31. What are the 2 factors that determine the capacity of an incinerator?
32. Why should care be taken to prevent excessive amounts of air entering the incinerator furnace when it is in operation?
33. Why is mosquito control so important at military installations?
34. What precautions must be taken in using a malathion concentrate for fly baits?
35. Ratproofing the sills and doors of a building is best done with
    (a) metal sheathing
    (b) cement
    (c) rodenticides
    (d) hardware cloth

CHAPTER 10

FOREMANSHIP RESPONSIBILITIES

As a petty officer with a general rating, you have additional duties beyond knowing the operating, maintenance, and repair procedures for systems and for equipment with which you will work. The Navy also expects you to be capable of instructing and supervising men in the service ratings, and passing on to them the information and the skill required for performing their parts in the overall Navy mission.

Having studied the preceding chapters, you probably realize more clearly than ever before the many and varied branches of technical knowledge that you must master in order to become a Chief Utilities Man. To instruct and train other men, you must thoroughly understand all the operations, the techniques, and the equipment that have been discussed here.

When you look over Section J of the Quals (in appendix II of this training course), you will see that your foremanship responsibilities can be roughly separated into three classes: those dealing with materials, those dealing with men, and those dealing with job operations. Naturally, these classifications are not distinct, watertight compartments, since there is always an overlapping of the three factors in any job that must be done. However, for purposes of the discussion in this chapter, the separation into materials, men, and operations is a practical one.

In relation to materials (which includes supplies and equipment both) your duties can be summarized under the following heads:

1. Preparation of requests for materials

2. Handling of work requests and job orders

3. Estimation of materials needed for specific jobs; this may include consulting blueprints and preparing sketches

4. Control of amounts of material on hand, by means of inventory and stowage controls

5. Control of the site deployment of materials and equipment

6. Preparation of reports on equipment, or on the operation of systems and mechanisms

In relation to job operations, your responsibilities are chiefly as follows:

1. Directing of installation, maintenance, and repair operations on all station facilities

2. Development of adequate operational procedures, looking toward efficient work methods, combined with a rigorous regard for safety

Your responsibilities with relation to the men involve the following factors:

1. Training and instructing lower-rated men

2. Supervising the work of lower-rated men

3. Knowing when and how to delegate responsibilities

4. Ensuring that necessary logs and records are properly maintained

One of the duties of a Chief Utilities Man is to prepare reports on the condition of equipment, the operation of various systems, and the progress of assigned tasks. In the case of equipment reports, you may have to prepare information not only for your immediate superiors, but also for the Bureau of Yards and Docks.

The wider the scope of your duties, and the more you must learn in order to perform them, the greater will be the demands made upon your time, your intelligence, and your enthusiasm. On the other hand, the greater will be your sense of worthwhile achievement, and your pride in becoming one of the key men of your organization.

CONTROL OF MATERIAL SUPPLIES

Tools, materials, supplies, and repair parts are an absolute necessity for the operation, maintenance, repair, and periodic overhaul of the wide assortment of mechanical

equipment in use at a Seabee installation. In the initial stages of the occupation of an advanced base, most of these necessary items will be taken care of through the Functional Component System.

After the initial phase (probably 90 days), or at a base already established, you will have an increasing responsibility for ensuring that you have what you need, when you need it, and where you need it. This means that you must know when it will be possible to requisition replacement or repair parts, and when it will be necessary to requisition new equipment. You must also be aware of needs well in advance of the time when you will make actual use of the equipment, since in many cases the materials and parts may have to come from supply centers hundreds or even thousands of miles away.

Your first impulse will be to oversupply your activity, to prevent any possibility of running short. This puts an undue burden on storage space, often inadequate at best; it may result in depriving another activity of critically needed items; it is almost certain to result in a considerable waste of supplies. You must give a great deal of thought and careful planning to the whole matter of supplies and equipment.

Maintenance of Inventories

The first step in making sure that you will have what you need, and when you need it, is to know what you already have, and where it is. For this purpose, you should maintain careful and accurate inventories of all equipment and supplies. Even such small items as fittings, piping, hand tools, and so forth, should be included in the inventory.

Stowage of these items should be so arranged that you can readily locate them when they are needed. Some type of record to show when they were released, and to whom, will be especially helpful in maintaining control of hand tools, which can so easily be borrowed and never returned.

On items of equipment classified as nonexpendable (Series 12000), and issued to your activity, you will be REQUIRED to keep an inventory. This nonexpendable equipment includes pumps, compressors, boilers, distillation units, and similar items.

When nonexpendable equipment is issued to your company officer, the supply officer requires him to sign a custody record. In turn, the company officer will require you (or other actual custodian) to sign a custody receipt when you take over the equipment. Once a year, the company officer must hold an inventory of these Series 12000 items, to determine if the record of equipment at the activity agrees with the record maintained by the supply officer.

Material Requisitions

A requisition is a request for material, made on a standard Department of Defense form, and presented at a Navy activity. A record of all items ordered must be kept, in order that the proper control of Navy supplies can be maintained.

The supply system will vary in minor details at different installations, but all systems require keeping a record of the items ordered. The requisition form will vary also, depending upon the type of material requested, and upon whether the request is presented to the stock room of the activity, or to a supply depot.

Most of the requisitions which you will make out will be for drawing material from the supplies at your own activity, and you will use DD Form 1150. This is the "Request for Issue or Turn-In" form, which superseded the old Stub Requisition, NavSandA Form 307. You may still hear older Navy men refer to these material requests as stub requisitions, or as "307's."

When you prepare requisitions, either to replace items drawn from inventory, or to secure items needed for the accomplishment of some assigned task, be specific and thorough. Give enough information so that the request itself may be identified later, if need be. This means that the requisition should have a number and a date; it should also be signed by the officer authorizing the requisition.

Describe the item, and give the quantity desired. The description of the item should be so complete that there is no danger of a similar item being provided by mistake. Use the description given in the Navy Stock List (usually the Bureau of Yards and Docks Section), and include the

stock or part number. If the item is not listed, give the name of the manufacturer, the part number, the assembly or subassembly number, a description of the use to which the article is put, and even, if possible, a sketch of the item. The idea, of course, is to identify the wanted item in such a way that even a person with no knowledge of its technical use can readily locate it.

In requisitioning needed materials, you should make a fairly long-range estimate of requirements. Consider the condition of your equipment, and the probable need of repairs or replacement parts. Your past experience will help you in arriving at realistic requests. Records of past usage, and manufacturers' recommendations, will also be practical guides.

However many copies of a DD 1150 are required, always have one extra copy that you can save for your own records. You can see how helpful it will be to have a carbon, when it becomes necessary or desirable, for any reason, to track down a request.

Work Requests and Job Orders

Regular attention to the maintenance requirements of operating equipment will keep the need for major repairs and overhauls to a minimum. Nevertheless, there will be times when the work that must be done on equipment or buildings under your supervision will call for the assistance of men in other ratings. In such cases, you will have to prepare a work request and have a job order issued.

The forms used for work requests and job orders are not identical at all activities. Study the system in use at your activity, and follow it. Be as specific as possible in writing work requests. Explain clearly and exactly what work is to be done, and indicate the type of special or technical knowledge required, and the number of men who should be assigned to the task.

The information that you give in the work request determines the job order. These latter forms are an important part of the public works officer's records, and the information which they carry becomes the basis for analyzing the performance of specific equipment.

There will also be occasions when you will be asked to supply a Utilities Man for accomplishing work in the area of some other rating. In such cases, you will receive a copy of the original job order. Read every job order carefully, and question anything that you do not understand. Only when you are sure that you understand what is required should you go ahead on the job. If you have a number of job orders to act on, take time to plan the work beforehand. When the orders are classed, arrange them so that each job will be done according to the priority assigned.

It is your duty to see that these jobs are done promptly and properly. Then notify the person who requested the work, and inspect it with him, whenever possible, to make sure that the results are satisfactory. Report the job completion to any other person who should know about it.

Estimations and Sketches

A good plan for any required job must include a careful estimation of the type and amount of material that will be needed. On all but extremely simple jobs, it will be greatly to your advantage to look up the blueprints of the equipment that is to be repaired.

If the blueprints have been properly kept, you will have not only the overall view of a piece of equipment, but you will also have the DETAIL PRINTS, showing designs and dimensions of unit assemblies and subassemblies, and indicating the material to be used.

These prints of individual parts will be especially useful guides when repairs must be made. Not only will you see the shape of the required piece, but you will be able to estimate, on the basis of the dimensions, how much material will be required to produce the piece.

In estimating the amount of material needed for any particular unit, decide what form it most closely approximates—that is, flat sheet, cone, sphere, or the like. You remember from your Basic Training Course in Mathematics that the area of a rectangular flat surface is the product of its length and its width. The volume, or total amount of material contained, is the area multiplied by the depth. The area of a triangular flat surface is one-half

the product of the base times the altitude; the volume is still the area multiplied by the depth.

So much for the relatively simple problems connected with estimating needed material for rectangular or triangular forms. But suppose you have something shaped like a pyramid. Its area will be the sum of the areas of the triangular sides, and the rectangular base (or triangular, or other straightline figure). The volume is one-third the area of the base times the altitude. A flat circular surface has an area of *pi* times the square of the radius ($3.14\ r^2$). The surface of a sphere is $4\pi r^2$; if the circle forms the base of a cylinder, the volume of a cylinder is the area of the base times the altitude. With these basic formulas, you can find the amount of material needed for any piece of work.

If you want a good job done, see that your men have a good understanding of what the piece should look like, know the dimensions, and have enough material for the work. If necessary, make a rough working sketch of the part to guide them. Indicate the dimensions on all sketches.

You can widen your knowledge of how to read blueprints, and how to produce working sketches, by a careful study of chapters 2, 3, 4, and 6, of *Blueprint Reading and Sketching,* NavPers 10077-A, one of the basic Navy Training Courses.

SUPERVISION AND PLANNING

The petty officer, particularly at the levels of First Class and Chief, is a key man in the planning and supervision of technical duties. First of all, the petty officer must have the knowledge of his technical field, or fields, that allows him to speak with authority. He must have the skill to deal with people, not only the service ratings under his supervision, but also men in related ratings. He must have the willingness and the ability to pass on his own knowledge, in the training of lower-rated men. He should have the imagination to see possibilities of effecting savings in time and money by developing improved work methods.

Knowing Your Men

Good supervisors take a keen interest in their men. This interest does not manifest itself in any form of prying into their personal affairs, in unsolicited or officious advice, or in an attitude of condescending patronage. It does manifest itself in a continuing concern for the technical advancement of these men, and a willingness to extend a helping hand when sympathy and friendliness can give needed support or encouragement in a time of personal trouble.

When you want to mold your men into a smoothly functioning unit, you must know their capabilities, their limitations; their general educational background, and something of their past performance. As you work with them, you will acquire a good idea of their temperamental characteristics, their ambitions, their hobbies, their recreation, and certainly their job understanding and skills. It will help you to know something of their home environment, and of their problems and difficulties; but these are matters into which you should not intrude without specific invitation.

Your contacts on the job are usually sufficient opportunity to appraise your men. As you supervise and train them, you will rapidly learn their skills and capabilities. Observation and informal chats will give you a reasonably good idea of the man as an individual.

If you will think back to the first job that you were assigned to, when you made Utilities Man Third Class, you will probably remember harboring some fears that you might not measure up to what was expected of you. Start your new men off right, by making them feel welcome in your organization, and by making clear to them just what is expected of them in the way of job performance.

Greet the new arrival in a friendly manner. If he wants to talk, listen to him in a friendly manner. Show him around; make sure that he knows the location, not only of the working spaces, but also of mess hall, barracks, Exchange, and of the Chaplain's office and the administration building. Introduce him to the people with whom he will work.

Find out what sort of jobs he has been doing, and what he can do. Tell him something of the overall work of your unit, and show him where he fits into the picture. Explain the local rules that he must follow, and the reasons for the rules.

If you are not going to train the man yourself, select his instructor carefully. Choose as trainer someone who is skilled enough to PERFORM, enthusiastic enough to INSPIRE, understanding enough to IMPART, and wise enough to APPRAISE. Do not simply assign this new man, and forget him. Go back after a day or two, and check on his progress. Let him know that he can come to you with questions, or for help.

When you have followed such procedures as these in introducing a new man to your unit, you have ensured that he will feel that he has been made a part of your organization, and he will be off to a good start.

Training Your Men

The job of training men in operational procedures can be more difficult in many ways than the job of learning these procedures yourself. The two main areas that will require special attention are: your organization of the material to be taught, and your attitude toward the trainees. You can get many helpful ideas for training programs from *The Shipboard Training Manual,* NavPers 90110.

ORGANIZING THE MATERIAL is a problem that you will have to work out for yourself; there is no single "best" way in which the subject matter should be organized. The important thing is to make sure that it is complete, omitting no step or no significant information. It should be arranged in a systematic and orderly manner, so that each step rests securely upon information already provided. There should be a minimum of overlapping, since repetition is a waste of time and of teaching effort, and usually leads to inattention on the part of trainees.

If too little instruction is given to new men, an activity may pay for this oversight not only in poor quality of work accomplished, but also in operation and maintenance costs, in high rate of accident, and in low rate of reenlistments. Haphazard training is probably as bad as insufficient training. Sound planning done in preparation for a

training program will simplify your responsibilities when you arrive at the later stages of planning for and directing the accomplishment of assigned tasks. Give yourself a few quiet minutes, at the beginning of planning a training program, to answer the following questions:

WHAT is the job that you want to teach?
WHO can best accomplish the training?
WHEN should the training be done?
HOW can it be done best; how much (or how little) is required?
WHERE should it be carried out?

WHAT you teach will inevitably be a combination of your own experience and of the knowledge that you have gained from reference books, operational manuals, and so forth. The reference material listed in chapter 1 of this training manual will be of great help here. If only one man is to be trained, analyze the duties of his billet, so that you will know what skills and knowledges his work will require of him.

The question of WHO will do the instructing is important if this is a duty you must delegate to some other man in your unit. The man you pick for instructor must have the following qualifications:

1. He must know the job processes that he is to teach, and he must have a reasonable skill in the performance of these processes.

2. He must know all regulations that control these processes, and prescribed standard operating procedures.

3. He must know how to handle men, so that he can maintain discipline and at the same time give the men a feeling of security.

The time for training is WHEN a new man joins a unit, or a new equipment or work process is added.

HOW the training can best be accomplished depends upon prevailing conditions and needs. As a general thing, the use of training aids should be a great help. Such aids are charts, models, mock-ups, films, and the like. One important thing to remember is that you never undertake training simply for training's sake; your program should be closely and realistically tied in to the needs of the activity.

The place WHERE the training takes place should be one where the men will be subjected to a minimum of

outside distractions. When you have located a quiet and suitable spot, see that all the necessary tools, equipment, and materials are assembled there.

Divide every job into operations. In some cases, job and operation will be identical; but in most cases, the job will be made up of several steps, or operations. For example, equipment maintenance would almost certainly include such diverse operations as cleaning, fueling, adjusting controls, testing performance of various parts under operating conditions, and replacing wornout parts. Figure 10-1 shows a job breakdown sheet for a sample job, in this case the steps to be taken before starting up a pump motor.

To prepare a breakdown sheet for any job, write the name of the job at the head of a sheet of paper; then think of as many separate operations as possible, and list these in the left margin. Number these in the order in which they should be performed. Then check to see if there are any omissions. When you are satisfied that you have a complete listing of the steps in the job, and that they are arranged in correct order, begin to fill in, on the right-hand side of the paper, all the key points in good performance of the step, and the safety aids or methods of accident prevention. Make up such a breakdown sheet for every job that is a part of the training program.

These job breakdown forms do not have to be elaborate. They are meant to be a help to the instructor, in reminding him of the points that he wishes to cover. They should have the effect of making the learning (as well as the instructing) easier, more accurate, and more rapid.

In the development of a plan for a training program, some form of a training timetable, such as that illustrated in figure 10-2, will enable you to ensure that every man has received training on every phase of the program.

A timetable like the one illustrated is an excellent device for showing what individuals are being trained, what training they are receiving, and how successfully they are responding to the training. List the names of the men who are being trained, and the various jobs that they must master. As a man demonstrates his mastery of a particular job, place a check against his name, and under that particular operation. Under job operations

JOB BREAKDOWN

JOB: Preparing the Continental engine of a Peerless Pump 6M for service

Important steps	Key points
1. Inspect hold down bolts.	Firmly set.
2. Open carburetor feed valve.	Counterclockwise handle as far as it will go.
3. Close water drain cock.	In lower radiator connection and L.H. side of block.
4. Examine oil drain.	Tightly closed.
5. Fill oil reservoir.	Through filler on left side of crankcase. Four quarts to "full" level. Clean container for filling.
6. Fill radiator.	Clean water. Replace tap securely.
7. Fill gasoline tank.	11 gallon capacity. Clean container for filling. Replace cap securely.
8. Pull out throttle control.	On front panel under radiator. Until carburetor throttle is 2/3 closed.
9. Turn ignition switch to "on" position.	
10. Pull out choker button.	At front of radiator.
11. Disengage clutch.	
12. Insert starting crank and turn the engine over.	Two or three times. Permit the engine to warm up before applying load.
13. Push in choker button.	Immediately after starting engine. Against radiator.
14. Start engine again.	If engine stops. Pull out choker button and insert starting crank.
15. Push choker button.	Part way in. Warm up engine before applying load. Never run after warming period with choker button pulled out.

Figure 10-1.—Sample job breakdown sheet.

that he need not know, you can place a dash. Indicate the dates when successful completion of training takes place.

This type of record can be put to other uses. It provides you with needed information when a question arises of personnel transfers or promotions, and it gives you a good basis for planning job assignments, and working out good methods of handling workloads.

TRAINING TIME TABLE Period: April-June ✓ Qualified — Not desirable at this time	Operating a pump	Servicing a pump	Operating a compressor	Servicing a compressor	Operating an oil burner	Servicing an oil burner	Operating a coal burner	Servicing a coal burner	Cutting pipes	Reaming pipes	Cutting internal threads	Cutting external threads	Cold bending pipe	Hot bending pipe	Joining pipes	Lagging fittings	Coagulating water	Conducting pH test	Conducting residual-chlorine test
Butler	✓	✓	✓	✓	5/13	5/10	—	—	✓	✓	✓	✓	✓	✓	✓	✓	—	—	—
Hildebrand	✓	✓	✓	✓	—	—	—	—	5/23	5/25	5/21	5/29	—	—	—	—	✓	✓	✓
Christmas	—	—	—	—	✓	✓	✓	✓	✓	✓	✓	✓	4/10	4/15	4/22	4/24	—	—	—
Oldaker	—	—	—	—	✓	✓	✓	✓	5/1	5/3	5/5	5/1	—	—	—	—	6/10	6/15	6/20
Cohen	✓	✓	✓	✓	4/20	4/17	5/20	5/17	—	—	—	—	—	—	—	—	✓	✓	✓
New man (to report 4/1)	4/3	4/1	4/27	4/25	—	—	—	—	6/1	6/5	—	—	—	—	—	—	—	—	—

Figure 10-2.—A training timetable.

Don't depend upon TELLING to get the necessary information across to the men; all the trainees will not take in a new idea at the same speed. Don't even depend upon SHOWING, for someone is sure to miss an important step.

Experience has pointed up the value of what may be called the "4-step" method of instruction. This method consists in first preparing the learner for the material; demonstrating it to him by both explaining and showing; testing him to see how well he has taken hold of the instruction; and then following up by making sure that he is continuing to do the job correctly.

In the first step, the preparation, put the trainee at ease, and explain the importance of the job, to him, to the unit, to the activity. Find out what specific knowledge he already has about this job. See that he has the tools and materials that he will require, and that he is instructed in the proper learning position—where he can see what you do, and pick up tools and materials without reaching or contortions.

In the second step, demonstration of the operation, you should enumerate each step of the operation, and stress the key points and the safety precautions. After you have described a procedure, go through it carefully. Question the men on tricky points. Do not give the men too much at one time, and do not hesitate to repeat the explanation and the demonstration, if some of the men seem to be slower than others in getting the idea.

The next thing is to test the trainee, to find out if he can do the job correctly. This is best done by having him do the job, under your inspection. Oftentimes, the learner will omit some process, or show uncertainty about some phase of the job. These will be his weak points, and you should stop him, give him any additional instruction, or question him on the key points involved.

If he performs the work operation exactly as you have taught it, do not conclude that he has completely mastered it. Have him do it again, or even a third and a fourth time. Question him on the what and why of his operations. Only when you are convinced that he understands the operation thoroughly can you safely check him off, on paper or in your own mind, as competent to be trusted to do the job by himself.

Most men will gain confidence and experience as they perform a job correctly, and without supervision. However, it is possible to forget some detail of a job, and this is especially true, of course, of the job that is done only occasionally. Therefore, you will find it is a wise plan to follow up the training with an inspection of the man's performance, after some time has elapsed. If the follow-up leads you to believe that the man's performance will be consistently reliable, you can turn your attention to the training of other units, or the training of the same man in other work operations.

Having the men study on their own initiative will add to the value of any training program. Encourage them to study available instruction manuals, or Navy publications that deal with subject matter closely related to that under discussion.

USAFI courses are open to men in active service, and the following are suggested as being particularly adapted to the educational needs of the men in Utilities Man service ratings:

C 760: *Plumbing*
C 761: *Air Conditioning, Heating, and Ventilating*
C 936: *Refrigeration*

Your Information and Education Officer will be able to counsel the men on available publications and courses, and to help them to take advantage of these opportunities.

Your ATTITUDE TOWARD TRAINEES will have far more influence than you might imagine in the degree of success with which you get your training material across to them. It is your duty to be on the alert for any indications that your men need training, or require assistance in developing desirable skills, knowledge, habits, and attitudes. All men do not learn at the same pace; some may need additional instruction or refresher training.

In your relation as instructor, you should strive to observe the following rules:

1. Be firm in holding your men to high standards.
2. Be patient with the men who are slower than others in taking in new ideas or learning new procedures.
3. Be impartial in your treatment of your men.
4. Avoid the use of sarcasm as a teaching device.
5. Maintain an even pressure of discipline.

6. Accept your share of the responsibility for getting information or training across successfully.

7. Be honest about admitting it when you do not know the answer.

You depend upon your men to get the work of your unit done properly, and therefore you have a duty to supervise and inspect. Don't let this develop, though, into supervision carried on from the sense of authority rather than that of responsibility.

Allow your men as much freedom as possible in their work, provided that results are satisfactory in quantity and quality. If you encourage them to make suggestions on how the work can best be done, they will take more interest in its successful completion.

Make the best use you can of each man's ability. Let him know how he is progressing; help him when his work is not up to standard; give him a word of praise when his performance is praiseworthy.

In any group of men, some will naturally be less satisfactory than others. There are two ways of dealing with an unsatisfactory man: you can always wait until you have accumulated sufficient evidences of his inaptitude or his poor morale, and take action; or you can talk things over with the man and try to discover the causes underlying his dissatisfaction or his poor job performance.

If your first reaction to an unsatisfactory man is to get rid of him, or to impose penalties, it is hard to see who gains by your course. The Navy doesn't benefit; the man is hardly inspired to make the effort to do better; and it is doubtful if you yourself will feel very happy over the matter.

Before taking any definite action, talk things over with the man in question, and try to get at the underlying cause. Give the man a chance to talk freely, and listen to him. Weigh the facts carefully. Interpret them, if necessary, in the light of facts disclosed in the man's record.

If unsatisfactory performance or other difficulties arise from insufficient training, poor working conditions, placement in the wrong type of work, excessive or insufficient supervision, or related reasons, the responsibility for correcting these conditions certainly rests with you.

If the man himself is careless, try to work out with him, and for him, a definite program for correcting the weak elements in his performance.

Your job, then, is to discover underlying causes, to weigh their importance, to interpret them in the light of other available facts, to discuss the situation with the unsatisfactory man, and to give him helpful and constructive criticism. Only when a man fails to respond to these measures will you consider employing sterner methods, or invoking penalties.

Many of the men with whom you work will be at the opposite end of the scale of efficiency and dependability. Make use of the superior accomplishments and abilities of these men to lighten the burden of training, inspection, and supervision which you must carry.

There are two advantages in having men to whom you may safely delegate authority to train or supervise, in your place. You will have so many responsibilities, that there will be times when your personal control of a given situation will be limited by time or distance factors, or by the number of men involved. As a training officer, you will want to develop the supervisory skill of your most capable men.

Whenever you put a man in charge of a job, make sure that he understands clearly what is to be done, and the extent of his authority in seeing that it is done. If he needs help, give it to him freely; encourage him to consult you if he has any questions whatever about the work procedures. From time to time, check with him on the progress of the work.

Make sure that you delegate enough authority to meet the demands of the situation, but remember that it is authority to get the work done that you delegate. Responsibility for the job, and for seeing that it is done on time, is always your responsibility, and cannot be delegated.

Planning and Directing Work

The best means of getting an assigned job done in the proper manner, and within desired time limits, is to carefully plan it beforehand, and direct it to make sure that results are satisfactory.

You will probably have job procedures already classified, in accordance with some scheme such as that indicated in figure 10-1. Your training timetable data (see fig. 10-2) will tell you what men are skilled in various job operations. With this basic information, you can systematize the steps to be performed in any task, and can assign the most capable men.

However, in distributing the work, be fair to the men; give each one the feeling that you recognize his competency to do the work. Never let the men feel that you are assigning jobs on a basis of partiality or favoritism. That is the quick and easy avenue leading to poor morale and poor production. Rotate each type of job as far as possible, so that all your men will get their chance to work on every type.

Make assignments clearly, so that each man will definitely know what is expected of him. Take care to avoid gaps in the assignment of work, and also to avoid overlapping. Do not assign an impossible amount of work to one man.

Schedule the work so that it will be done in the correct sequence. Timing is important, especially when you have groups working on separate sections of a job that will ultimately form one complete operation.

There will be occasions when you will have to work with men of other ratings. It may be that men with the ratings of Steelworker, Builder, Construction Electrician, and so on, will be assigned to help with some of your work. It may be that you will be called upon to help a chief petty officer of another rating, in accomplishing work for his unit.

If you are using the services of other ratings, coordinate your assignments, by making up working groups of men who are most likely to be congenial. Assign the work in the right amount, in the right manner, and to the right men.

When you have to give assistance to another unit, be cheerful and helpful in your services. Avoid any type of personal competition or friction that would impede the accomplishment of the work.

IMPROVING WORK METHODS

When you can improve the method of doing a job, so as to save time or materials, simplify processes, or in any way achieve better results, you and your unit demonstrate that you have a high level of technical competence.

The first step in improving established work methods is to preserve an open mind toward changes. When checking on the progress of your men on any assigned work, ask yourself if the operation in use is the best way of doing the job. Particularly when the men as a whole experience difficulties, you should test the effectiveness of the method being used.

First, analyze the present way of doing the job, listing each step in sequence. Study each action, considering the amount of effort that has to be put into it, the time that it demands, and any other pertinent work details. It is important that every step be listed completely, so that you can get a true picture of skills required, and time and effort involved.

Give your men an opportunity to express their opinions on the efficiency of the present method, and to make any suggestions that they have for improvement.

Go through the listing, step by step, studying the possibilities of substituting suggested steps; look at each step carefully, to judge whether it could safely be omitted. Weed out all unnecessary actions. If you are in doubt about any changes, consult your superior and get his opinion. This is a good way to eliminate those steps that became a part of the process by way of hit or miss filling in.

After this elimination process, go over the sequence of steps again, with the idea of possible simplifications, rearrangements, or combinations. You can readily see the advantages of simplifying processes; rearrangements and combinations can often serve to save materials and time.

Write your new method now in the form of a correct sequence of steps. Have your men test the operation on trial runs, and check the results very carefully. Then submit the new method for approval. It is advisable to submit old and new listings of steps together, with a short summary of the advantages of the new method, including

any proposed savings. Pictures, sketches, or layouts accompanying the proposed method may help to make your ideas clearer, and win approval for them.

Savings in reduced time of operation, in materials, and/or in use of equipment are one type of benefit that may come from improved work methods. Ease of performance, with a more rapid mastery of techniques, is another benefit. A safer and more foolproof way of getting a job done is a third possibility, and an important one. Any one of these results represents an important contribution, and one in which you and the men of your unit may justly take pride.

INSTALLING SPECIAL EQUIPMENT

From time to time, you will be called upon to install new equipment at a Seabee installation, and this equipment may be anything from a new piece of galley equipment to a 50 hp boiler. Study the instructions compiled by the manufacturer, and shipped with the new material or mechanism. When you are quite sure that you understand these instructions, begin the work of installing the equipment.

Remember that all motor-driven equipment must be installed on a foundation firm enough to prevent the equipment from being damaged by vibration.

The installation of fuel supply systems must be carried out very carefully, because of the dangers both to equipment and personnel if these systems do not perform as required under operating conditions.

Install pumps as closely as possible to the systems that they will feed. Keep the suction lift within the narrowest possible limits; if possible, place the pumps so that suction will take place by gravity flow.

Be careful to see that electrical appliances and equipment are connected only when you are sure that the power source provides the appropriate voltage and current.

Plan the location of refrigerated spaces so that the length of time that they are opened to outside air can be held to a minimum.

Locate incinerators so that the soot, ash, and odors coming from them will not be a hazard to the health or comfort of the personnel at the activity.

At least two copies of an instruction booklet will be included with all new equipment. After you have studied these manuals, and installed the equipment, place these manuals with your supply of technical publications, and other sources of information. These manuals will provide you with the knowledge necessary for settling any questions that arise in connection with operation and maintenance.

OPERATIONAL REPORTS

Your foremanship duties include the keeping of numerous forms of operational data, and the preparation of reports for the commanding officer of your activity. You may be called upon to provide the information for, or to help in the preparation of, various reports required by the Bureau of Yards and Docks. Many of the reports that you maintain will help you and your men to discover what is wrong with a piece of equipment, and will guide you in making repairs or replacements.

To make these reports serve the ends for which they are intended, you must first make certain that they are being kept, regularly and accurately. If the information is recorded only when the item or equipment is not performing satisfactorily, you will not find it especially helpful. If the information represents a guess, however shrewd, it is not going to have the same value as the actual data taken from a controlling or indicating device.

Your first obligation, therefore, is to instruct your men in the accurate recording of the necessary data. You must impress upon them the necessity of making these records accurate, and of entering the data at specified times. Then you must supervise and inspect, to make sure that they understand these duties, and are performing them as required.

See that these reports are filed in such a manner that they are readily accessible when the need to consult them arises. In an emergency, you will not want to be pawing through a mass of paper, wondering where you put the inventories of supplies on hand; the boiler logs; the maintenance records on that centrifugal pump that you want to have replaced; the records of temperatures and pressures in the refrigeration system; the results of chemical

tests on drinking water and boiler feedwater; and all the other records which relate to the equipment operated and maintained by the Utilities Man.

Work out a system of filing these records, so that you can put your finger on what you want, whenever you must advise and oversee in the case of repairs or trouble shooting, or when you must supply information for a report to higher authority.

SAFETY RESPONSIBILITIES

As a Utilities Man First Class, and especially as a Chief Utilities Man, you will have a serious responsibility for the safety of your men, for the safe operation of your equipment, and for the safe storage of repair parts, tools, and material supplies entrusted to your care.

Your responsibility toward your men includes instructing them carefully in the operation and the proper maintenance of the equipment which they will use. You must teach them the safety precautions that they should observe, and you must supervise and check on their work practices until you are sure that they are following all the prescribed precautions.

Safety in the boiler spaces is of paramount importance, since there are so many possibilities of casualties, from flarebacks and explosions primarily. The men must know the safety requirements in handling compressed gas cylinders for refrigeration systems, and in handling the refrigerant in the system. They must be warned of the necessary precautions in handling electrical contacts, and must know when they should call upon the aid of a Construction Electrician for trouble shooting or repairs.

In relation to water systems, and to waste and refuse disposal, there are also elements of safety to be considered. Piping for a water system must be so located that there is no danger of contamination of the water supply by seepage of sewage or other drainage into the water pipes. In sewage plants there is always the possibility of explosive gases to be guarded against.

Training your men in pest control includes educating them in the use of protective clothing, when they are handling insect repellents and sprays.

Safe maintenance of equipment includes such factors as: correct installation; operation by proper procedures, and within rated capacity; periodic inspection, cleaning, and repair.

Safety precautions in relation to supplies includes care in storage; they should be put where they cannot be damaged by drainage, contamination, or fire. The proper handling and protection of food supplies is particularly important.

QUIZ

1. What are 3 disadvantages, as mentioned in the text, of overordering supplies for your activity?
2. Once a year, your company officer must hold an inventory of
    (a) all supply items
    (b) hand tools
    (c) 12000 Series items
    (d) 13000 Series items
3. What is the form which you will most frequently use in requisitioning materials from your activity supplies?
4. When you are preparing a requisition, what Navy publication will usually provide you with a detailed description of the item?
5. The forms used for work requests and job orders are usually drawn up by
    (a) specific activities and installations
    (b) Construction Battalion supply centers
    (c) Bureau of Yards and Docks
    (d) cognizant fleet commands
6. According to the text, what 4 qualities are important to the petty officer who must plan and supervise technical duties?
7. What will probably be your best means of appraising the abilities of lower-rated men?

8. The 2 main areas in presenting a training program in operational procedures will be
   (a) your own ability to perform the jobs, and your attitude toward the men
   (b) your own ability to perform the jobs, and the number of men to be trained
   (c) the difficulty of the job processes, and the number of men to be trained
   (d) the organization of the material to be taught, and your attitude towards the men
9. When the quality of work produced at an activity is poor, the reason is usually
   (a) lack of proper equipment
   (b) too little instruction given to new men
   (c) high operation and maintenance costs
   (d) high accident rate
10. Should a training program be a continuous operation, regardless of how well the men know how to perform their duties?
11. The 4-step method of instruction consists of what 4 stages?
12. Should you always hold your men to strict observance of established job procedures?
13. What should be your first step in dealing with a man whose job performance is unsatisfactory?
14. In putting a man in charge of a particular job, should you delegate to him your authority and responsibility also?
15. What 2 types of records are suggested in the text as a guide in systematizing job procedures and assigning capable men?
16. The basic step in improving the method of doing a specific job is to
   (a) save time and materials
   (b) check frequently on the progress of your men
   (c) have an open mind toward changes
   (d) simplify technical processes
17. What 3 important benefits are listed in the text as possible results of improved work methods?
18. What is your overall duty with respect to logs and operational reports?

CHAPTER 11

SMALL UNIT COMBAT TACTICS

Under wartime conditions, a Navy Construction Battalion at work on an advanced base project must be capable of transforming itself instantly into an efficient combat organization. This means that battalion petty officers must be ready at any time to transform themselves from construction artisans and supervisors into leaders of rifle squads or fire teams. From this it follows that battalion petty officers must have an over-all general knowledge of the battalion's basic combat organization, plus a particular knowledge of the organization, tactics, and techniques of the rifle squad and the fire team.

BASIC COMBAT ORGANIZATION

For combat purposes, a full-strength construction battalion is divided into 1 headquarters company and 4 rifle companies. Each rifle company contains from 3 to 5 platoons, including a headquarters platoon and a machine gun or a heavy weapons platoon. In this discussion, we are concerned only with rifle platoons, which vary from 1 to 3 per rifle company. Headquarters company consists mainly of personnel in the administrative and supply ratings (such as Yeoman and Storekeeper), but there are a few Seabee ratings in this company also. Seabees attached to headquarters company perform duties related to intelligence and operations functions.

A rifle platoon consists of platoon headquarters and four rifle squads. Platoon headquarters consists of an

officer who leads the platoon, a chief, and eight riflemen. The chief is the senior petty officer in the platoon, who acts as second in command.

You should understand that the combat organization described above is only a recommended organization. The actual combat organization will depend upon the number of personnel in the battalion and the tactical situation.

The rifle squad and the fire team are the basic units around which small unit combat tactics are built. The rifle squad is divided into three fire teams, each of which is built around an automatic weapon. Each fire team is directed by a fire team leader. The fire team is the largest rifle unit that is controlled directly by a single individual.

The squad leader, then, is in charge of 3 maneuver elements, which he controls through the 3 fire team leaders. The fire team leader, in turn, has direct charge of an automatic rifleman, an assistant automatic rifleman, and rifleman. Small-unit combat tactics may be divided into those which apply to the squad and those which apply to the fire team.

RIFLE SQUAD TACTICS

The rifle squad leader carries out the orders issued to him by the platoon commander. He is responsible to the platoon commander for the discipline, appearance, training, control, and conduct of his squad at all times, and for the condition and care of its weapons and equipment. In combat he is also responsible for the fire discipline, fire control, and maneuver of his squad. He takes position where he can best carry out the orders of the platoon commander, while at the same time observing and controlling the squad. He participates in the fire fight only in critical situations.

The squad leader receives his orders from the platoon leader, who will usually designate a specific target or targets, and/or a sector of fire for the squad. If practicable, it is usually desirable for each squad to cover the entire target designated for the platoon. This procedure, which should be followed unless otherwise ordered, ensures adequate target coverage.

In attack, fire units must be trained to place a large volume of accurate fire upon designated enemy locations. Fire is used in the attack to gain and maintain the initiative through fire superiority over the enemy, and also to establish a base of fire from which to cover the maneuver of other units of the attacking force. The squad and the fire teams must be trained to apply fire quickly upon order or signal made by the leaders—and, in appropriate circumstances, to apply it without such order or signal.

During the fire fight, the primary duty of the squad leader is to place and control the fire of his unit on enemy targets. The squad leader should especially keep in mind the fire power of the automatic rifle, and he should direct the placement and maneuver of fire teams in such a manner as to allow maximum scope for the employment of this weapon. Positions selected should be those from which the heaviest automatic rifle fire can be delivered on any target holding up the advance. Whenever possible, a position should be one which permits the automatic rifle to fire across the entire squad front.

In defense, the fire of a rifle squad is delivered by fire teams placed in defensive positions. Teams should be placed where they can obtain good fields of fire, while taking advantage of maximum cover and concealment. Again it must be remembered that the bulk of the fire power of a fire team lies in the automatic rifle, and that the automatic rifle must therefore be both protected and kept in operation.

In the occupation of a platoon firing position, the selection of locations for squads in the platoon area, and for fire teams in the squad area, should be based upon a number of tactical considerations. To the fullest extent possible, a selected squad or fire team position should be one which

1. Will provide desired fire support
2. Gives a good field of fire to the front
3. Provides maximum cover and concealment
4. Facilitates exercise of fire control by the squad leader.

Squad Formations

The term "squad formation" applies to the tactical arrangement of the three fire teams in the squad. Each of

the basic squad formations implies a particular fire team formation, or a particular tactical arrangement of the individuals in each fire team. Fire team tactics, including formations, will be discussed later.

Basic combat formations for the squad are: (1) column (fire teams in column or wedge), (2) wedge, (3) vee, (4) echelon (right or left, fire teams in wedge), and (5) line (fire teams in wedge or skirmishers right and left). These formations are shown in figures 11-1 through 11-8.

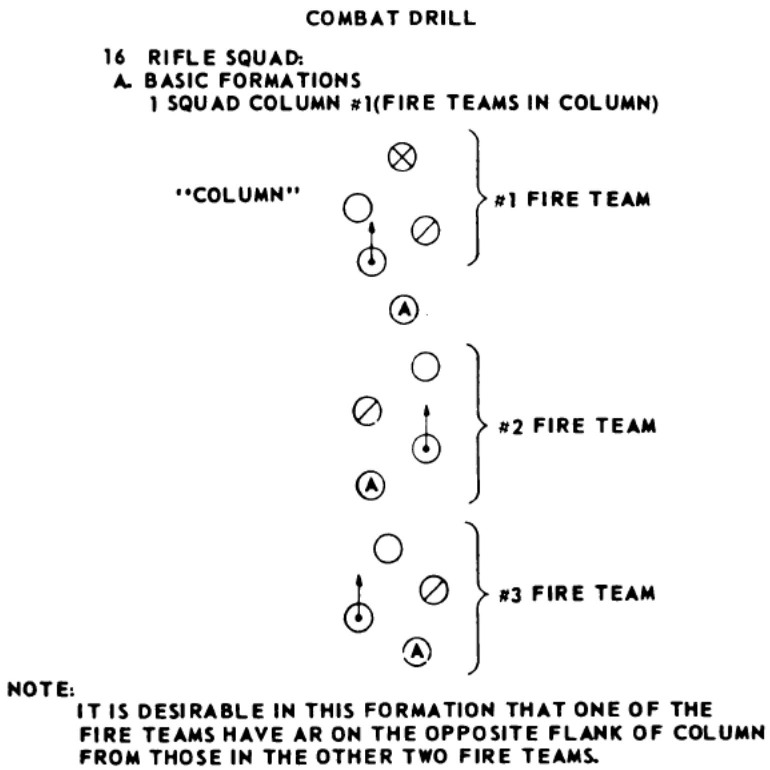


Figure 11-1.—Squad column, fire teams in column.

The tactical considerations which apply to each of these formations are as follows:

1 & 2. The squad column, in which the fire teams are arranged in succession one behind the other, is a formation which is vulnerable to enfilading fire from the front, and which requires a shift in formation to bring maximum fire power to the front. However, it is a formation which can be easily controlled and maneuvered. It is especially suitable for narrow, covered routes of advance; for maneuvering through gaps between areas receiving hostile artillery fire; for moving through woods; and for moving in fog, smoke, or darkness.

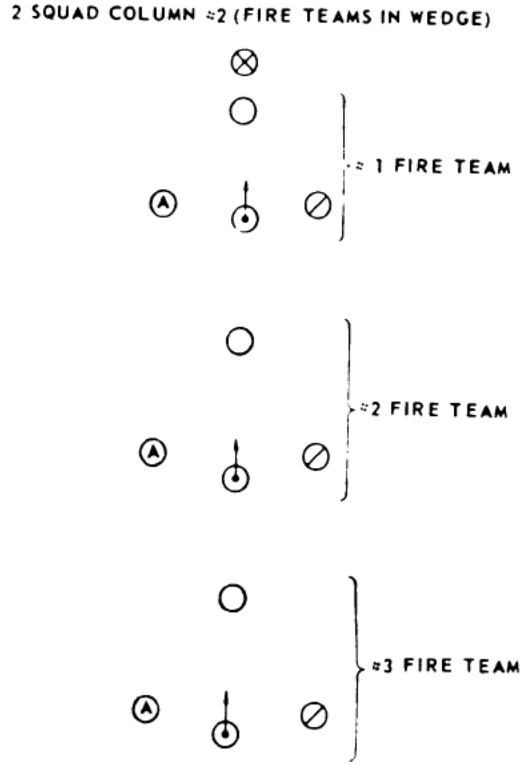


Figure 11-2.—Squad column, fire teams in wedge.

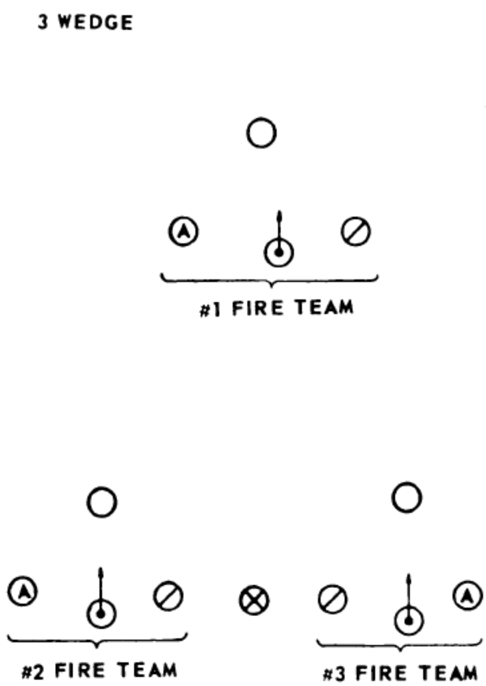


Figure 11-3.—Squad wedge, fire teams in wedge.

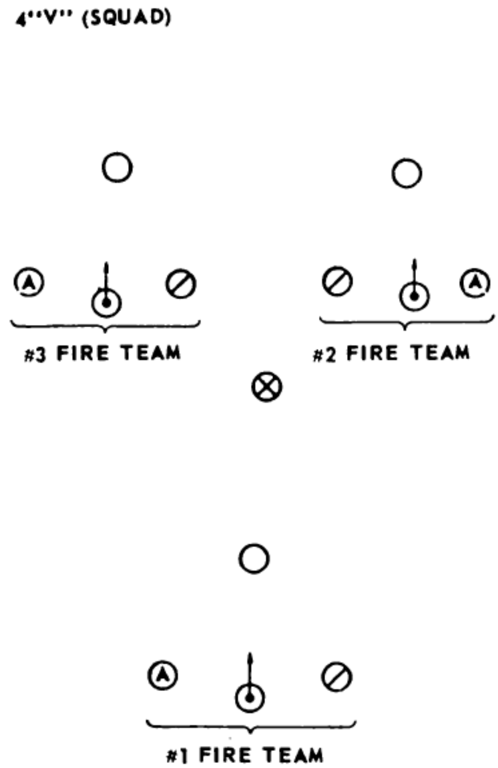


Figure 11-4.—Squad vee, fire teams in wedge.

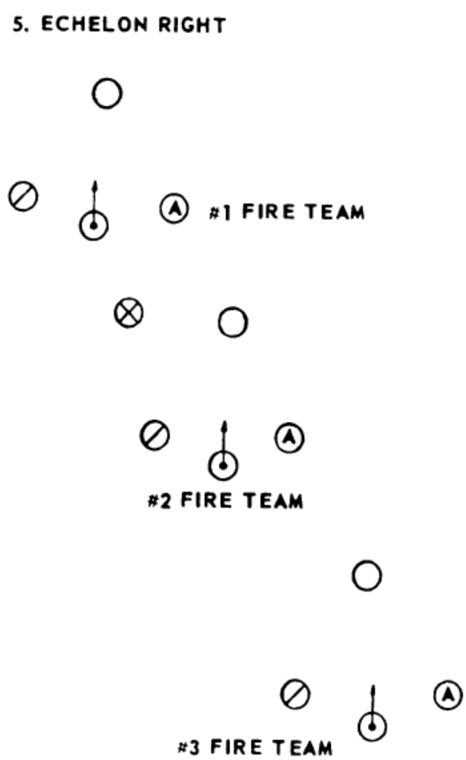


Figure 11-5.—Squad echelon, right, fire teams in wedge.

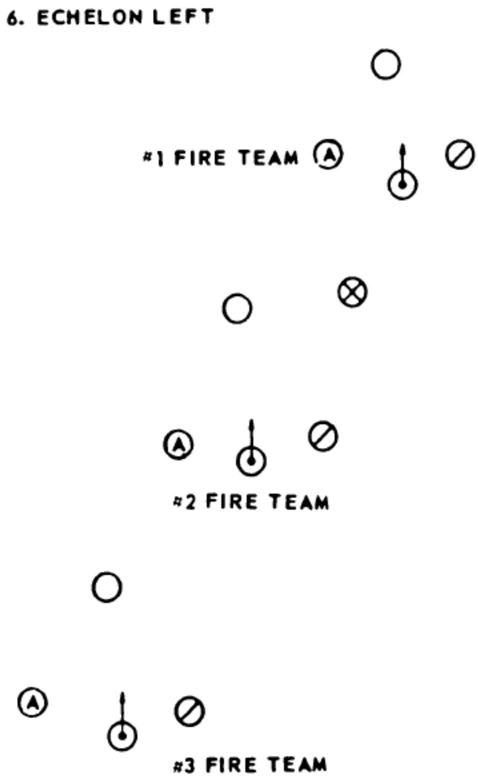


Figure 11-6.—Squad echelon left, fire teams in wedge.

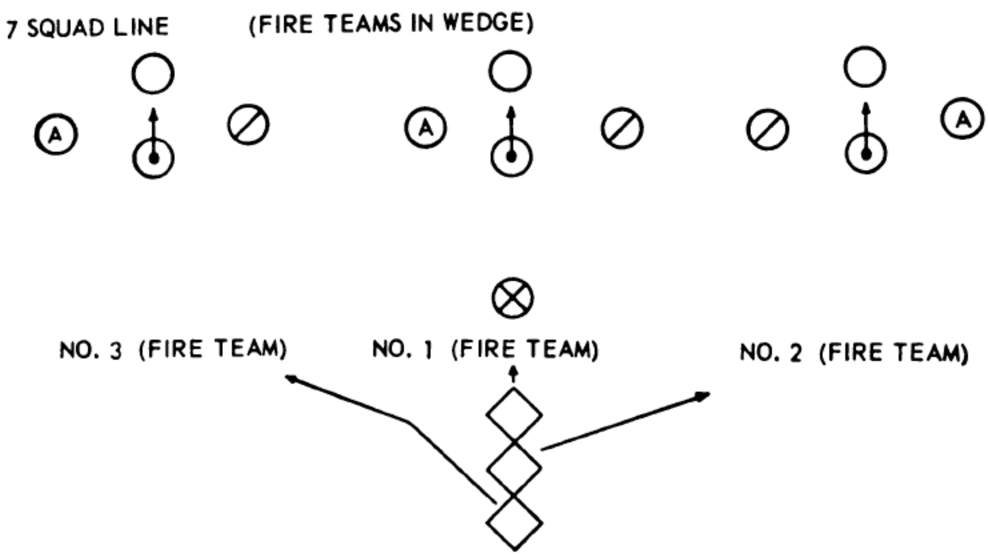


Figure 11-7.—Squad line, fire teams in wedge.

3 & 4. Squad wedge and squad vee are formations which provide security on both front and flanks, facilitate maneuver and control, and provide flexibility in meeting

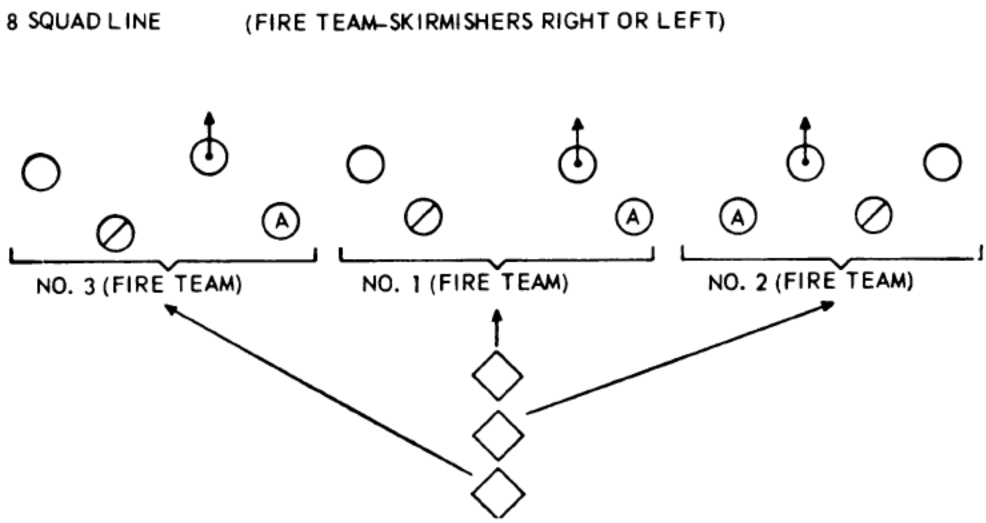


Figure 11-8.—Squad line, fire team skirmishers right and left.

new tactical situations. Which of the two formations is the more suitable depends upon the nature of the terrain, the frontage which the squad must cover, and the proximity and activities of the enemy.

5 & 6. Squad echelon right/left is a formation in which the fire teams are placed diagonally one behind the other, with echelon to the right/left. This formation is used to protect an exposed flank. It makes it possible for the squad to deliver maximum fire promptly on the right/left flank or toward the right/left front.

7 & 8. Squad line is a formation in which the fire teams are placed in line, or abreast of one another. This formation makes it possible for the squad to deliver maximum fire power to the front in the shortest possible time. The formation is less easily controlled than most of the others, but it is also less vulnerable to fire from the front. It is the best formation for crossing an area exposed to hostile long range machine gun fire from the front, or to artillery fire which cannot be avoided.

FIRE TEAM TACTICS

The squad leader controls the activities of the components of the squad through the fire team leaders. The fire team is the largest rifle unit that is controlled directly by a single individual. Every member of the fire team must know and understand the duties and responsibilities

of every other member, and each must be prepared to assume any position on the team when necessary.

A fire team consists of a leader, an automatic rifleman, an assistant automatic rifleman, and a rifleman. The fire team leader carries out the orders of the squad leader. He is responsible to the squad leader for the employment of his team in combat, for its fire discipline and fire control, and for the condition and care of its weapons and equipment.

In combat the fire team leader takes position where he can best carry out the orders of the squad leader while observing and controlling the team. He must be near enough to the automatic rifleman to exercise constant and effective control over the team's major weapon. Besides his primary function, the fire team leader also serves as rifleman and grenadier, and the senior fire team leader serves as assistant squad leader. Within each fire team, the next senior man to the leader serves as assistant fire team leader.

The automatic rifleman carries out the orders of the fire team leader. He is responsible to the leader for the most effective employment of the automatic rifle in combat, and for the condition and care of that weapon and of his other equipment.

The assistant automatic rifleman carries out the orders of the fire team leader. He is responsible to the leader for assisting the automatic rifleman in keeping the automatic rifle in effective action at all times, and for the condition and care of his own weapon and equipment. One of his primary duties is to protect the automatic rifleman by covering him with his own rifle. He maintains the ammunition supply for the automatic rifle, helps to clear stoppages, identifies targets, and replaces the automatic rifleman if the latter becomes a casualty. He also serves as general rifleman, scout, and grenadier.

The rifleman carries out the orders of the fire team leader, usually by serving as general rifleman, scout, and grenadier. He is responsible to the fire team leader for the effective employment of his rifle in combat, and for the condition and care of the rifle and his other equipment.

Fire Team Formations

The basic fire team formations (wedge, column, skirmishers left, and skirmishers right) are shown in figure 11-9. Figures 11-10 to 11-19 illustrate the manner of changing from one of these formations to another. Tactical considerations which apply to each of the four basic fire team formations are as follows.

The column formation lends itself readily to rapid, well-controlled movement. It is vulnerable to enemy fire

BASIC FORMATIONS

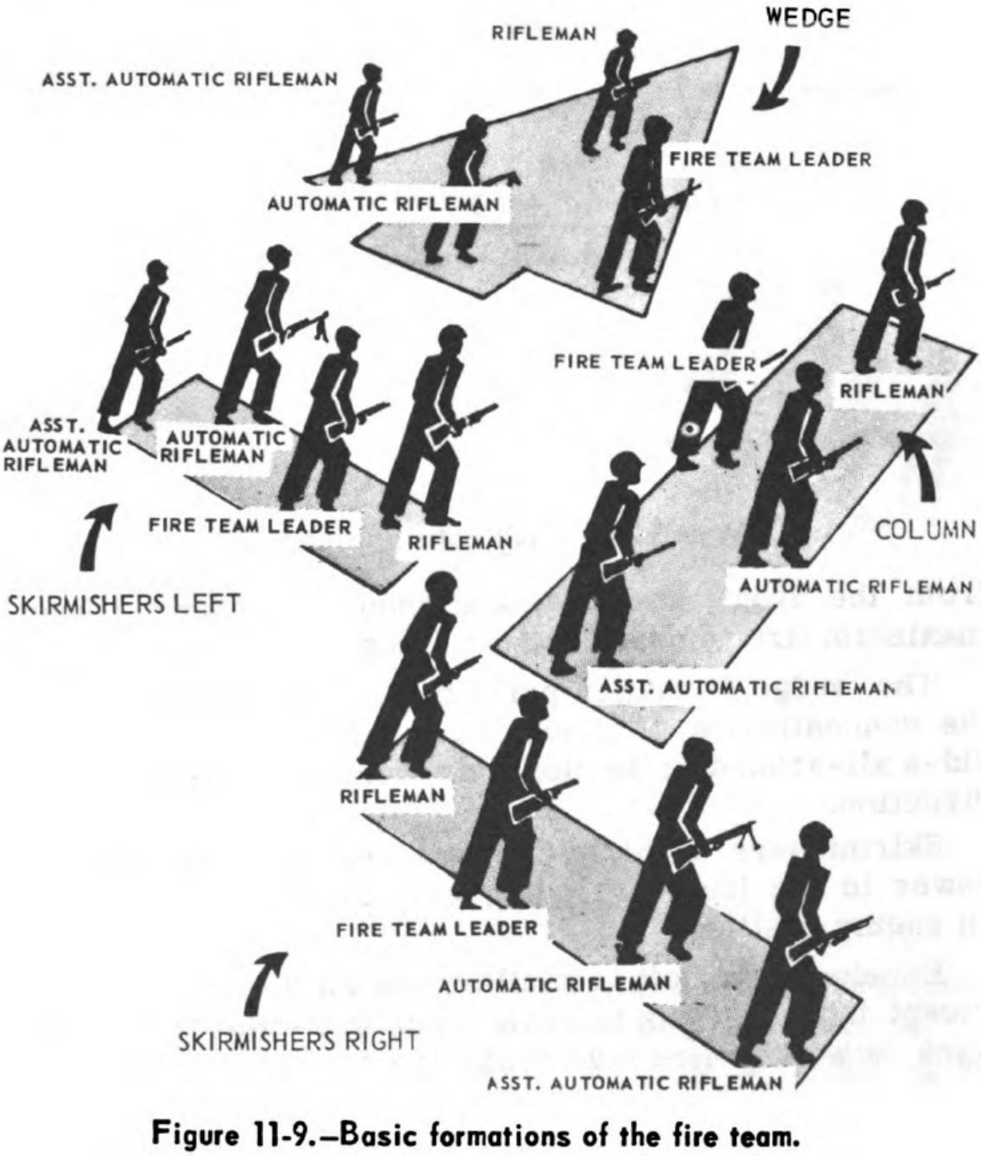


Figure 11-9.—Basic formations of the fire team.

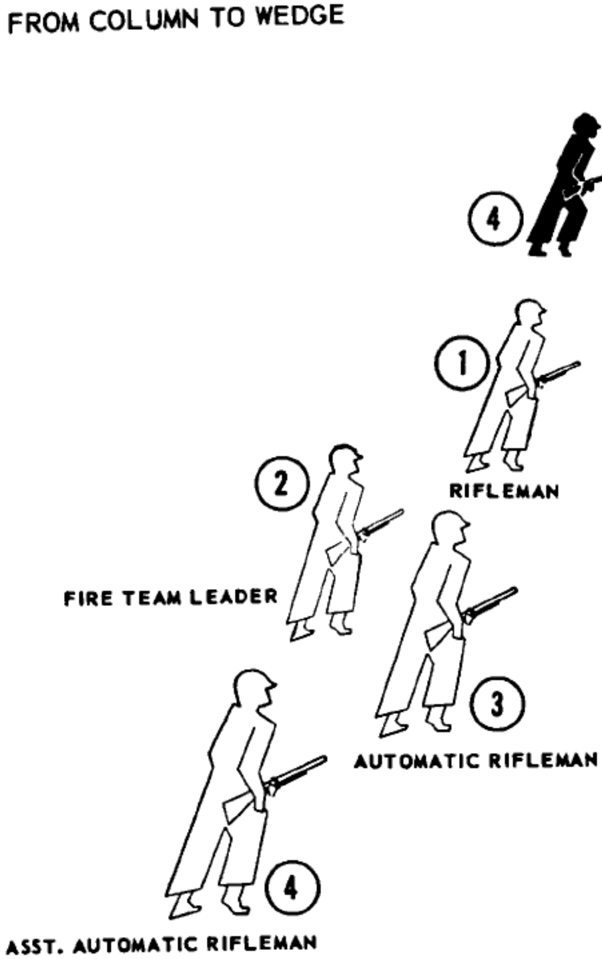


Figure 11-10.—From column to wedge.

from the front, however, and should be changed when maximum fire is needed to the front.

The wedge formation permits good control as well as the concentration of almost all fire to the front. It provides all-around protection and readiness for action in any direction.

Skirmishers right/left allows use of maximum fire power to the front. It is best employed in an assault on an enemy position.

Echelon right/left is similar to skirmishers right/left, except that one flank is drawn back to permit fire on the flank as well as fire toward the front.

Tactical considerations applying to each member of the fire team are as follows:

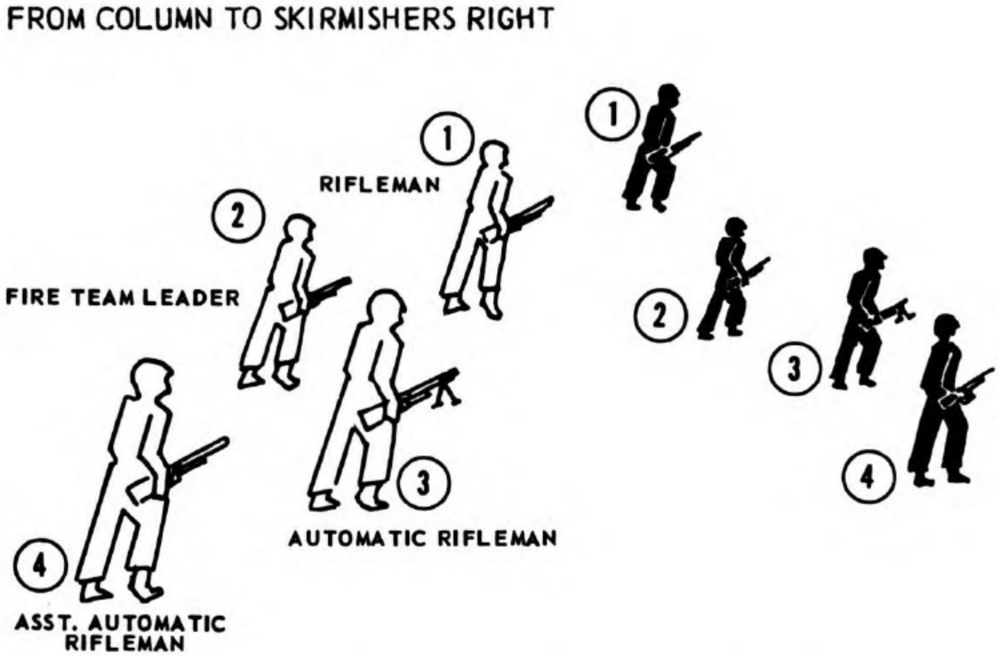


Figure 11-11.–From column to skirmishers right.

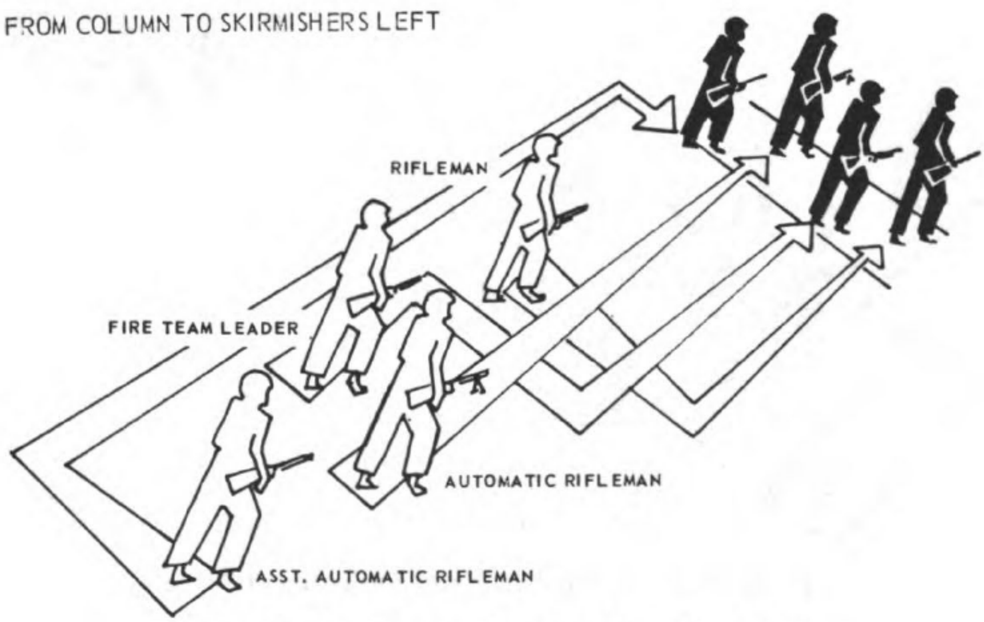


Figure 11-12.–From column to skirmishers left.

The fire team leader places himself in a position from which he can best (1) observe the tactical situation, (2) control the team, (3) receive the orders of the squad leader, and (4) quickly and effectively control the employment of the automatic rifle.

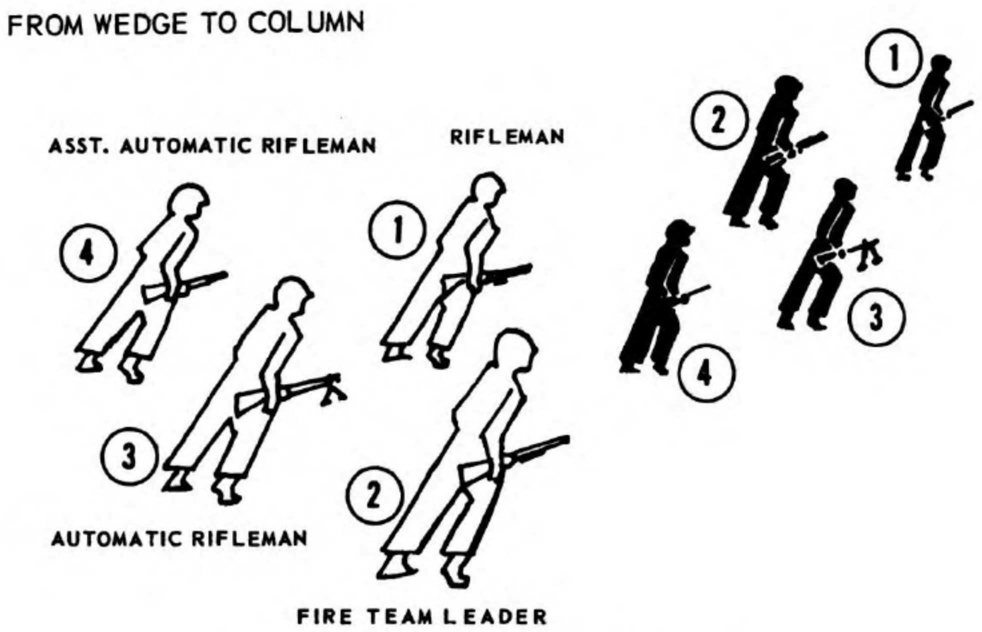


Figure 11-13.—From wedge to column.

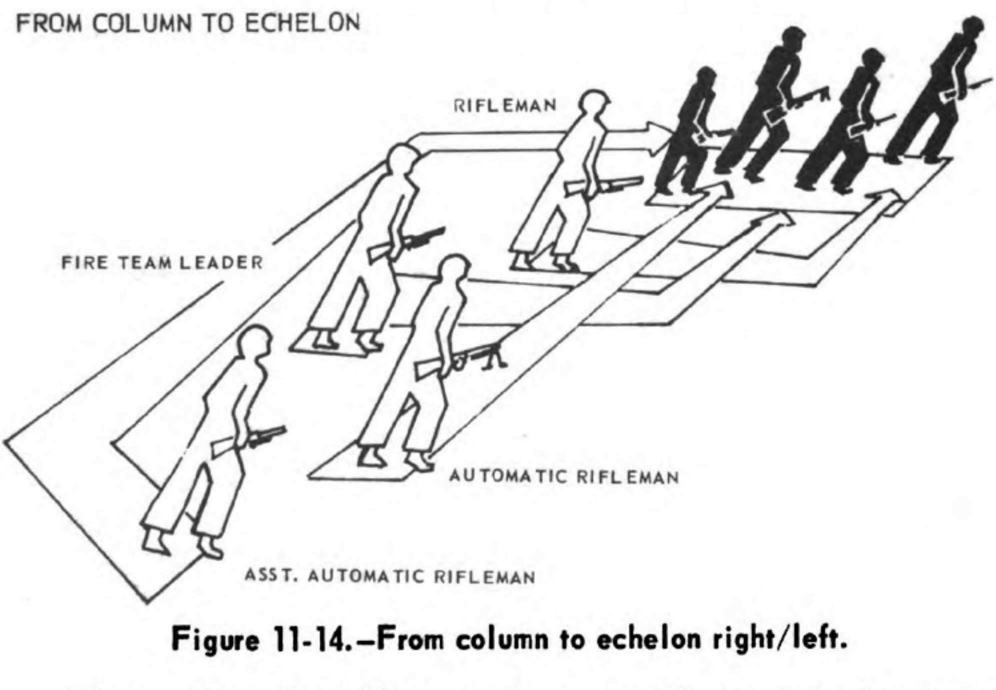


Figure 11-14.—From column to echelon right/left.

The automatic rifleman is normally an interior man within the fire team formation. His position is usually between that of the fire team leader and that of the assistant automatic rifleman. In such a position he can (1) deliver instant and effective fire as ordered by the fire team leader, and (2) receive the assistance and protection of the assistant automatic rifleman.

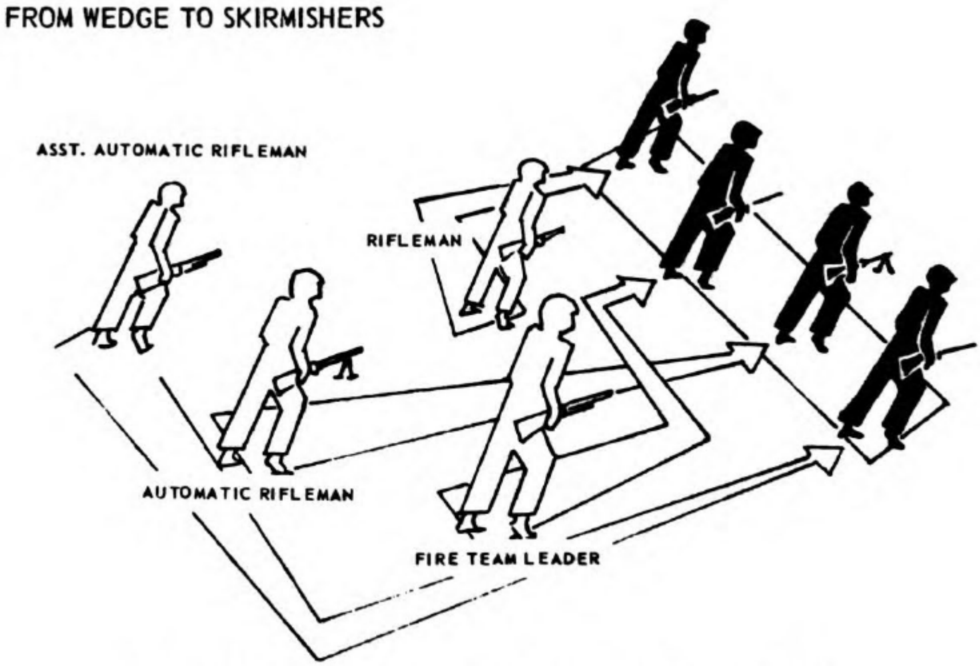


Figure 11-15.—From wedge to skirmishers right/left.

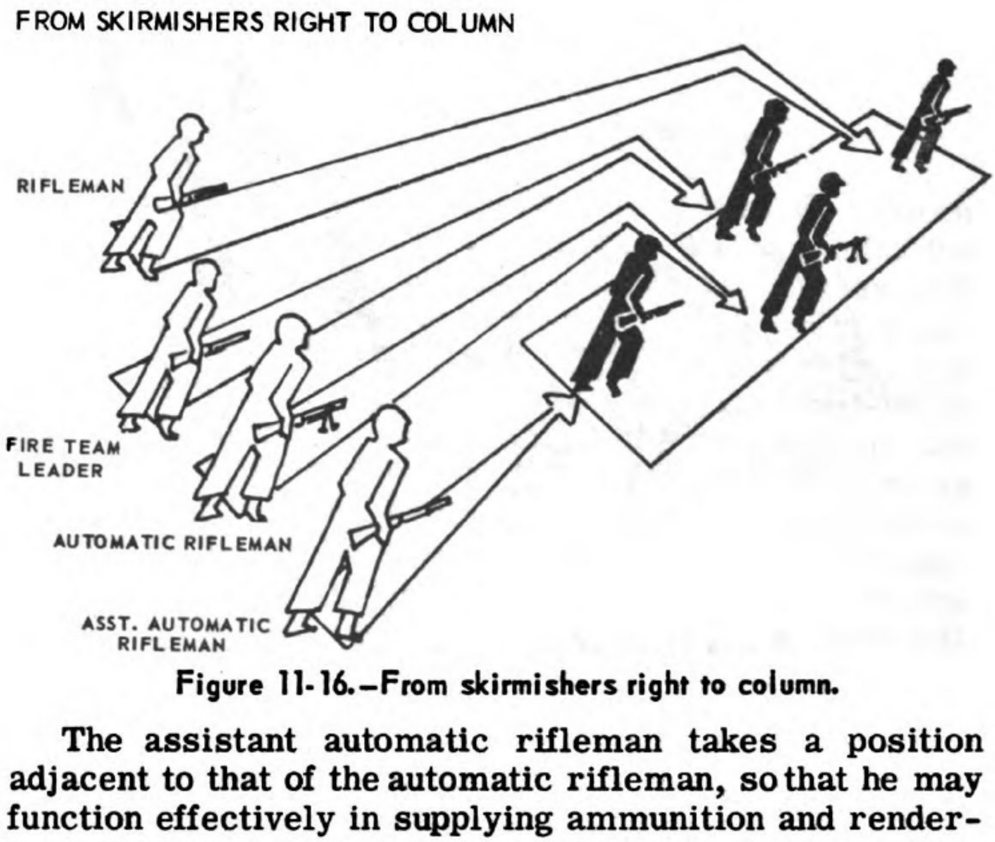


Figure 11-16.—From skirmishers right to column.

The assistant automatic rifleman takes a position adjacent to that of the automatic rifleman, so that he may function effectively in supplying ammunition and rendering other assistance. He coordinates both his position

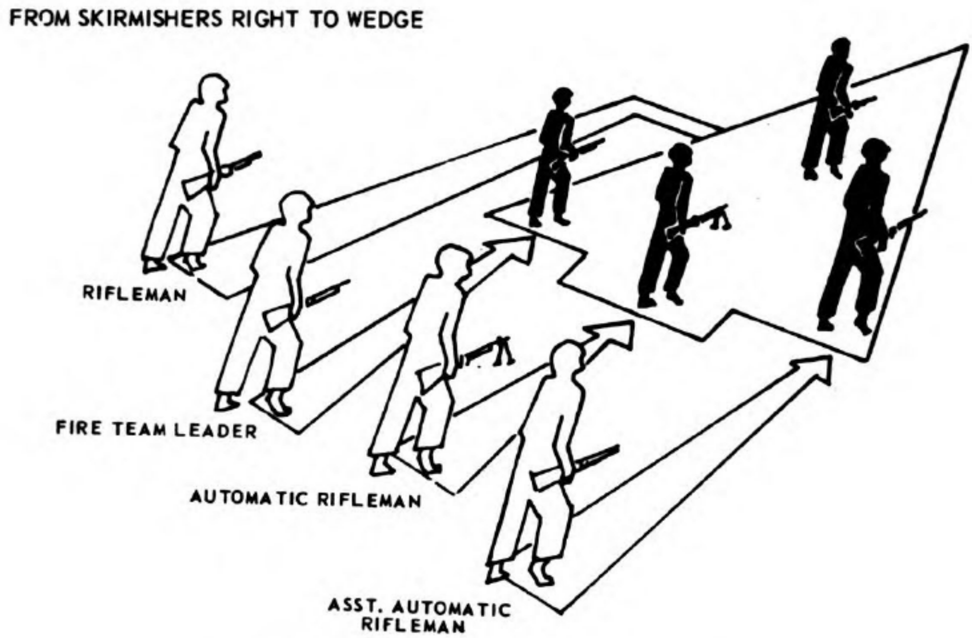


Figure 11-17.—From skirmishers right to wedge.

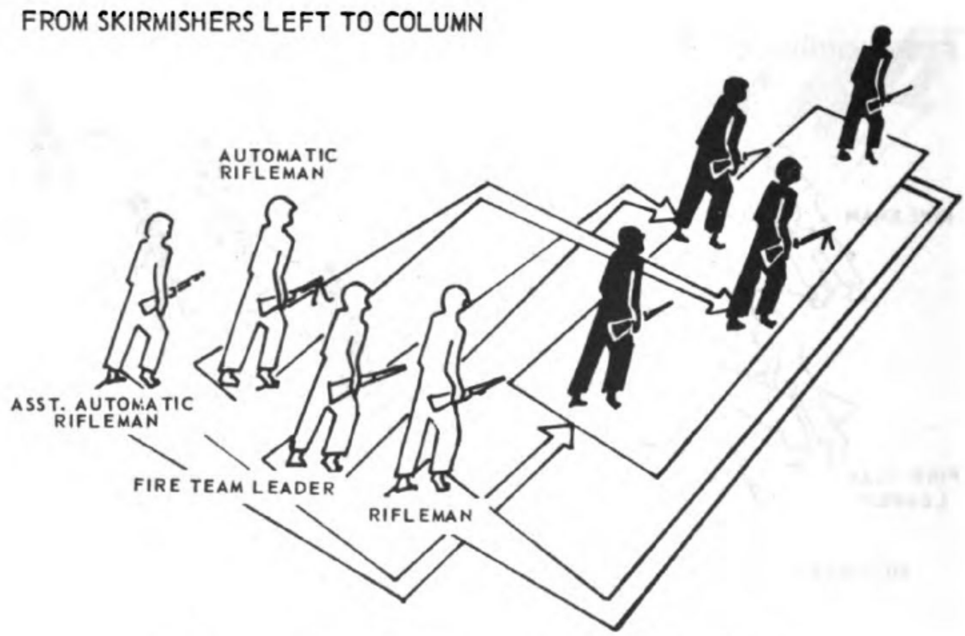


Figure 11-18.—From skirmishers left to column.

and his movement with those of the automatic rifleman, and replaces the latter as necessary.

The rifleman should be located at that point of the fire team formation which is most threatened by actual or probable enemy action. If the team is advancing, the

FROM SKIRMISHERS LEFT TO WEDGE

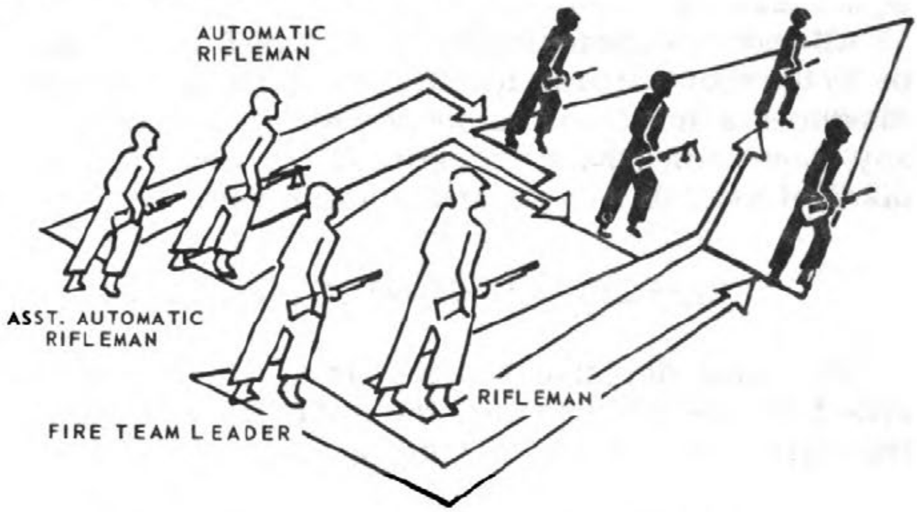


Figure 11-19.—From skirmishers left to wedge.

rifleman should be in the foremost position. If the team is withdrawing, the rifleman should bring up the rear. If the team is placed on an exposed flank of the squad formation, the rifleman should be placed on the corresponding flank of the team formation. In short, the rifleman functions continually as the team's security element.

USE OF FORMATIONS

Initial formations are usually ordered by the platoon commander for the squads, and by the squad leader for the fire teams. Subsequently, however, each leader may shift the formation of his unit in accordance with such circumstances as enemy activities, changes in terrain, and changes in tactical mission. Consequently, although there is a fire team formation which is more or less appropriate to each squad formation, a squad may contain fire teams which are in a variety of formations, and these formations may be shifted frequently to take advantage of circumstances. In any event, the tactical disposition of the fire teams in a squad must never be one in which one team will mask the fire of another.

It is not essential that exact distances and intervals be maintained between fire teams, or between individuals in a team, as long as good control is maintained. Sight or voice contact should be maintained within the fire team,

and also, when practicable, between fire team leaders and squad leaders.

All movements incidental to shifting formations should be by the shortest practicable routes. Backward or lateral movements must be avoided whenever possible. During any movement, the greatest possible advantage must be taken of available cover and concealment.

EFFECT AND CONTROL OF FIRE

The most decisive results from rifle and automatic rifle fire are obtained when the unit is close to the enemy. Normally, fire should not be opened at ranges greater than 500 yards, which is the maximum effective range of the rifle. Under favorable conditions, however, the automatic rifle may be used at ranges from 500 to 1,000 yards.

The best way to determine the enemy's location is to estimate his distance and direction from the sound of his firing. To cover the position of an invisible enemy with fire, men should aim their shots at likely firing positions, such as bushes, rocks, stumps, patches of long grass, and folds in the ground.

When the proximity of a target has been discovered, leaders and squad members making the discovery must be able clearly to define its location and nature. A small point target, such as an enemy sniper, may be assigned to only 1 or 2 riflemen. A target of considerable width, such as an enemy skirmish line, or a target area in which the enemy's precise location is unknown, calls for the combined fire of the entire squad. As an aid to the designation of various types of targets, all members of the squad must become familiar with the significance of such topographical terms as crest, hill, cut, fill, ridge, bluff, ravine, crossroads, road junction, and skyline.

Once the squad leader has decided to open fire on a specific target, he must issue orders to the fire team leaders, informing them of the character and location of the target and of the manner in which it is to be engaged. An order of this kind is called a FIRE COMMAND. A fire command contains six basic elements, as follows:

Alert—Direction—Target description—Range—Target assignment—Fire control

The alert brings the unit to a state of readiness to receive further information. It usually consists of the command or signal SQUAD (or FIRE TEAM). Signaling methods will be discussed later.

The direction element in the fire command informs all hands of the direction in which the target lies. Approximate target direction is indicated by the words FRONT, RIGHT FRONT, LEFT FRONT, RIGHT FLANK, LEFT FLANK, RIGHT REAR, LEFT REAR, and REAR. More exact direction may be shown by pointing with the arm, by aiming with the rifle, or by firing tracers. It must be remembered, however, that tracers may disclose your position or spoil a surprise.

To help the members of the squad locate an invisible or indistinct target, a conspicuous REFERENCE POINT may be indicated, together with the target's position with regard to the reference point. When using a reference point, use the word REFERENCE in designating the point and the word TARGET in designating the target. A typical alert and target designation might be the following:

SQUAD
FRONT
REFERENCE: BUSHY PINE IN DRAW
TARGET: SNIPER IN FIRST BUSH TO THE RIGHT

Following the target designation, the estimated range in yards should be given. Next comes the target assignment, stating who is to fire on the target. Frequently the "who" has been announced in the alert element. If, for example, the entire squad is to open on the target mentioned above, the absence of any specific target assignment will serve to indicate that fact. On the other hand, if the squad leader desires to have only the first fire team open on the target, the words FIRST FIRE TEAM will follow the target designation.

The fire control element consists of a command or signal to open fire. If surprise fire is not required, the command COMMENCE FIRING is normally given immediately after the target assignment, if any. If the squad leader wants all his weapons to open simultaneously, so as to obtain maximum surprise and shock effect, he prefaces the command or signal to commence firing with the words AT MY COMMAND or AT MY SIGNAL. When all hands are ready, the leader gives the command

COMMENCE FIRING. This command may be prefaced by qualifying elements which limit the type or extent of the fire, as: BAR, ONE MAGAZINE, COMMENCE FIRING—BAR, ONE MAGAZINE, SHORT BURSTS, COMMENCE FIRING—FIRE TEAM, ONE CLIP, COMMENCE FIRING.

COMBAT SIGNALS

Oral communication is, for a variety of obvious reasons, frequently impossible under combat conditions, and a system of sound and arm-and-hand signals has been set up to cover most of the necessary combat commands. Practice in the use of these signals, and also in the use of any improvised signals devised to cover deficiencies in the standard system, must be made a constant feature of combat training.

Whistle Signals

The order to "Cease firing" is a long blast on the whistle, followed by the arm-and-hand signal which means the same thing. Arm-and-hand signals will be illustrated and explained later. Three long blasts on the whistle are also given to warn of approaching enemy planes or tanks. Three long blasts on a vehicular horn, siren, or klaxon, or three equally spaced rifle or pistol shots, or three equally spaced short bursts from a machine gun, have the same significance. At night the whistle alarm should be supplemented by oral designation of the direction from which the enemy is approaching.

Arm-and-Hand Signals

A platoon is alerted by the signal PLATOON (fig. 11-20), a squad by the signal SQUAD (fig. 11-21), and a fire team by the signal FIRE TEAM (fig. 11-22). For PLATOON, extend both arms forward (hands with palms down) toward the leader(s) or unit(s) for which the signal is intended, and describe large vertical circles with the hands. For SQUAD, extend one arm and hand (palm-down) toward the squad leader, and move the hand up and down by pivoting on the wrist.

Figure 11-20.–
Platoon.

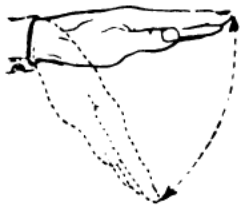


Figure 11-21.–
Squad.

Figure 11-22.–
Fire team.

When a shift in formation is desired, a preparatory signal SHIFT is given first (fig. 11-23), followed by the signal for the desired formation.

Figure 11-23.–
Shift.

Figure 11-24.–
Wedge.

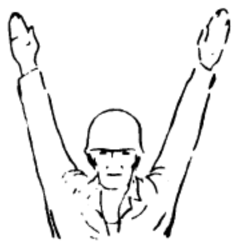


Figure 11-25.–
Vee formation

Desired formations are indicated by the signals WEDGE (fig. 11-24), VEE FORMATION (fig. 11-25), AS SKIRMISHERS (fig. 11-26), AS SKIRMISHERS RIGHT/LEFT (fig. 11-27), COLUMN (fig. 11-29) and ECHELON (fig. 11-30). The manner of signaling WEDGE and VEE FORMATION is obvious in the illustrations. For AS SHIRMISHERS, extend the arms horizontally, with hands palms-down. To indicate direction of advance as skirmishers, signal FORWARD (fig. 11-28) while moving in the desired direction.

To signal for a COLUMN formation (fig. 11-29), extend one arm horizontally toward the leader(s) or unit(s) for whom the signal is intended. Then drop the arm and hand to the side and begin an up-and-down movement of the arm from the side to the horizontal front. To signal for an ECHELON formation (fig. 11-30), extend both arms

Figure 11-26.–
As skirmishers.

Figure 11-27.–
As skirmishers
right/left.

Figure 11-28.–
Forward.

horizontally toward the leader(s) or unit(s) concerned, and close both fists. Then draw the fist on the side toward which the echelon alinement is desired back to the chest.

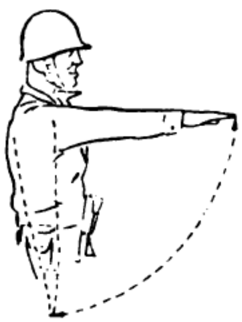


Figure 11-29.–
Column.

Figure 11-30.–
Echelon.

Figure 11-31.–
Change direction.

To signal CHANGE DIRECTION (fig. 11-31), carry the arm and hand which is on the side inclined toward the new direction across the body to the opposite shoulder, holding the forearm horizontal, hand palm-down. Then swing the forearm in a horizontal plane until the arm and hand are pointing in the new direction.

To signal ENEMY IN SIGHT (fig. 11-32), hold the rifle horizontally above the head, with the arm or arms extended as if guarding the head. ENEMY IN SIGHT is frequently followed by DOWN or TAKE COVER (fig. 11-33). To make this signal, turn toward the unit or group and, with elbows at the sides, extend the forearms horizontally forward, with hands palms-down. Then simulate a downward pushing motion.

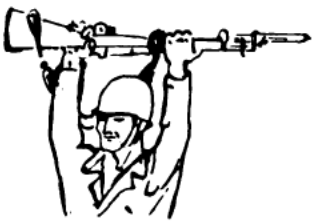


Figure 11-32.—
Enemy in sight.

Figure 11-33.—
Down or take
cover.

Figure 11-34.—
Are you ready?
or I am/we are
ready.

A leader checks the readiness of the unit to engage, or to take some other action, by the signal ARE YOU READY? (fig. 11-34). An indication of readiness is made by the same signal which then signifies I/WE ARE READY. To make the signal, extend the arm toward the leader or unit for whom it is intended, holding the hand palm-toward the leader or unit.

FIX BAYONETS (fig. 11-35) is signaled by simulating the action of fixing a bayonet. COMMENCE FIRING (fig. 11-36) is signaled by extending one arm horizontally forward, with hand palm-down, and moving the arm and hand in a series of wide circles. Desired rate of fire is indicated by the speed at which the arm is revolved. CEASE FIRING (fig. 11-37) is signaled by placing the arm approximately in saluting position, but with hand held palm-forward, and describe a series of arcs by passing the hand back and forth across the face. Leaders are assembled, to receive orders or for some other necessary reason, by the signal LEADERS JOIN ME (fig. 11-38). All hands are assembled by the signal ASSEMBLE (fig. 11-39). To make the signal, raise one arm vertically overhead, holding the hand with fingers extended and joined, and then describe wide circles with the arm and hand.

Sentry Duty

You should already be familiar with sentry duty requirements, since that subject is covered in *Basic Military Requirements*, NavPers 10054.

Figure 11-35.—
Fix bayonets.

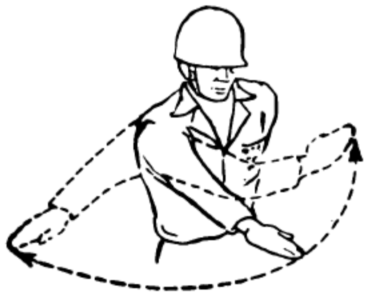


Figure 11-36.—
Commence firing.

Figure 11-37.—
Cease firing.

Figure 11-38.—Leaders join me.

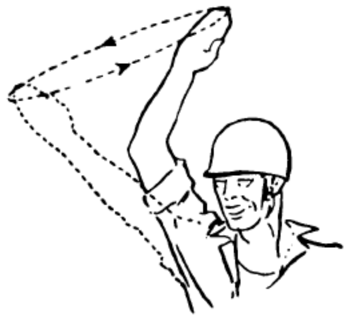


Figure 11-39.—Assemble.

QUIZ

1. How is a full-strength Navy Construction Battalion organized for combat purposes?
2. Describe the organizational structure of a rifle company, a rifle platoon, a rifle squad, and a fire team.
3. What are the general duties of a rifle squad leader during combat?
4. What are the basic rifle squad formations?
5. Which of the basic rifle squad formations is most vulnerable to enfilading fire from the front?
6. Which of the basic rifle squad formations makes it possible for the squad to deliver maximum fire both to the front and on the right flank?
7. Describe the general duties of each member of a fire team during combat.
8. What are the four basic fire team formations?
9. Which of the basic fire team formations allows the use of maximum fire to the front?

10. Which of the basic fire team formations provides all-around protection and readiness for action in any direction?
11. Which member of a fire team is normally an interior man in the fire team formation?
12. What are the six basic elements in a fire command?
13. If a squad leader desires to obtain maximum shock and surprise effect by a sudden, simultaneous fire of all weapons, he prefaces the command COMMENCE FIRING with what command?
14. What is the whistle signal for CEASE FIRING?
15. How are the following arm-and-hand signals made? (1) squad alert, (2) as skirmishers, (3) change direction to the right, (4) enemy in sight, (5) commence firing, (6) cease firing.

APPENDIX I

ANSWERS TO QUIZZES

Chapter 1

NEW DUTIES AND RESPONSIBILITIES

1. The 3 important factors that make a successful petty officer are: knowledge, teamwork, and leadership.

2. The promotion from service rating to general rating carries the responsibility for cross-training service rating personnel for advancement to the general rating.

3. The Chief Utilities Man or First Class needs a knowledge of the practical factors in the UT service ratings qualifications in order to plan work schedules and training programs for lower-rated men.

4. The UT preparing for an examination for advancement in rating should consult NavPers 10052 to learn what texts and training courses will be used as references by the examining authorities.

5. The text suggests that any order to a lower-rated man should include these 4 factors: what is to be done, when it is to be done, how it is to be done, why it is to be done.

6. The Seabee petty officer will need self-reliance and resourcefulness in meeting unexpected situations.

7. The practical value of pride in your branch of the service is that such a pride promotes morale, efficiency, and teamwork.

8. The leadership qualities of a petty officer are made evident in the success with which he teaches and trains his men, and stimulates them to learn and accomplish.

Chapter 2

BOILERS AND BOILER CONTROLS

1. The essential parts of any type of boiler are: a space in which heat is generated, a space for water, and a space into which steam can escape.
2. (b).
3. (c).
4. Dual solenoid valves installed on a horizontal fire tube boiler ensure that fuel will be cut off at the time of boiler shutdown, since if one valve fails to close, the other will take over.
5. Installing a large drum in a horizontal fire tube boiler ensures (1) that the furnace will be sufficiently far from the drum shell to prevent unequal heating of the shell surface, and (2) that there will be little risk of a serious fluctuation in water level.
6. The 3 trycocks on a water gage provide an additional means of checking water level when the boiler is in operation.
7. A steam pressure gage reading of zero indicates atmospheric pressure only in the system.
8. (c).
9. A correct fuel-air mixture is desirable in order to prevent warping of metal surfaces, accumulations of soot or explosive gases in the smokestack, and other difficulties that will detract from efficient operation.
10. When sputtering of an atomizer occurs, you should immediately take suction from another fuel oil tank.
11. Oil suction may be inadvertently lost while a boiler is in operation if (1) the control valve in the fuel oil line is accidentally closed, (2) the fuel oil becomes contaminated with water, (3) the oil level in the tank falls to suction level, (4) the oil is not heated to a point where it has the necessary fluidity, (5) heavy residue oil has settled to a point above the suction, and (6) suction is being taken from a tank too far from the boiler.
12. (a).
13. Before lighting off a furnace, run the forced draft fan for at least 5 minutes, to vent any accumulated gases.
14. If a low water casualty is allowed to occur, not only will there be a drop in steam pressure, but the metal surfaces that are no longer immersed in water may be seriously damaged.
15. The 5 possible causes of a low water casualty, as listed in the text, are: (1) feed pump failure, (2) leak

in feed line, (3) defective check valve or cutout valve, (4) plugged gage glass, (5) water too low in tank.

16. After securing a furnace, remove the atomizers as soon as possible, so as to prevent carbonization of fuel remaining in the tips.
17. (a).
18. The 3 causes for accidental extinguishment of a burner are: (1) water mixed with oil, either in the fuel tank, or from a leaky heater; (2) burner choked with solid matter, due to strainer failure or to carbonizing of the oil; and (3) air entrapped in the fuel line, between pump and atomizer.
19. (d).
20. (c).
21. (d).
22. The chemical treatment given boiler feedwater (1) prolongs the life of the boiler by reducing corrosion and scale formation, and (2) effects a saving in fuel consumption.
23. (b).
24. Idle boilers may need feedwater treatment, to prevent corrosion of the metal.
25. An initial water treatment is desirable for new boilers, because of the possibility that oil and foreign material may be present in water and steam spaces.
26. Most fuel oil analyses are made in properly equipped laboratories.
27. The fire point, or burn point, of fuel oil is the temperature at which the oil remains ignited after flashing.
28. (b).
29. (d).
30. (b).
31. (b).
32. After a hydrostatic test has been completed, determine fitness of the boiler for use by testing and setting the safety valve.
33. For inspection or repair work within a boiler, a hand flashlight is the safest type of light to employ.
34. If a recently replaced gasket blows, the probable cause is failure to set it evenly when it was being installed.
35. Never attempt to relight a burner from a hot brick wall, because of the danger of flareback.

Chapter 3

PUMPS

1. The 3 usual methods of classifying pumps are: by operating principle, by power drive, and by type of service.
2. c.
3. Discharge head denotes either the liquid level on the discharge side, with respect to pump level, or the pressure on the liquid leaving the pump.
4. When a pump is to be installed, careful consideration must be given to location, foundation, alignment, and head.
5. b.
6. Check the alignment of coupling halves twice--first with the halves separated, then with them connected.
7. d.
8. a.
9. Greater friction loss occurs at bends and fittings than in an equivalent distance in straight piping because of the turbulence created.
10. No. Frictional loss in the 3-in. diameter pipe will be many times greater than in an equivalent length of 6-in. pipe.
11. In a reciprocating pump, rotary motion of the crankshaft is converted to straight-line motion of the piston by means of the connecting rod.
12. d.
13. On a steam-driven reciprocating pump, the joints of piston rings are staggered to prevent a free path for escaping steam.
14. b.
15. If the steam piston of a reciprocating pump that has been idle for some time freezes when the pump is put into service, inspect the main steam valve for overriding or sticking.
16. b.
17. If a properly packed gland continues to leak after it has been given a few turns on the nut, the probable cause is that the throat bushing is too large.
18. When a reciprocating pump is working so poorly that you know it is in need of repair, check the water end first.
19. c.
20. Before a centrifugal pump is started, after being lined up for use, it must be completely filled with water.

21. The volute type of centrifugal pump is better for use with liquid that contains grit or suspended matter.
22. The guide-vane multistage centrifugal pump is better than the volute pump when volume of liquid pumped is small in relation to the head.
23. When flow is reduced or stopped in a centrifugal pump, the extent to which pressure builds up is limited by the design of the pump, and is always well within the strength of the pump system.
24. In the choice of a site for a centrifugal pump, suitability for the driving mechanism is the first consideration, since the driving mechanism is usually more vulnerable than the pump itself to poor operating conditions.
25. a.
26. It is advisable to strain the water before it enters the suction line of a centrifugal pump because sandy or gritty water can wear away the impeller until it becomes unbalanced, causing vibration and even breakage of the crankshaft.
27. If you close the discharge line valve in a centrifugal pump, and let the pump remain in operation, the water circulates in the pump housing and grows hot.
28. Continued operation of a centrifugal pump with a leaky seal between pump and engine will allow water to enter the crankcase, emulsifying the oil and damaging the bearings.
29. If a centrifugal pump fails to deliver water after it is put into operation, check for the following 4 factors: clogged impeller, insufficient priming, too low an operating speed, or rotation in the wrong direction.
30. If a centrifugal pump begins losing capacity after it has successfully been put into operation, check for the following 3 factors: leak in suction line, too high a suction lift, or plugged water seal.
31. A rotary gear pump has only 2 moving parts: the intermeshing gears that revolve on parallel shafts, but in opposite directions.
32. The liquid passing through a rotary gear pump is prevented from leaking back to suction by the intermeshing gears and the close tolerances in the gear chamber.
33. c.
34. Since clearances must be kept to a minimum in a rotary pump, operation must be at a relatively low speed, to prevent wearing of the gear teeth.
35. All internal parts of a rotary pump are lubricated by the flow of the liquid being pumped.

36. When a rotary pump fails to build up discharge pressure, check the 3 following factors: insufficient priming, poor suction, or air leaks.
37. The 3 essential parts of a Hi-Lift pump are: turbine pump, plunger pump, and Hi-Lift pump.
38. The 5 component parts of an air lift pump are: air compressor, receiver for compressed air, air pipe to borehole, rising main, and receiving tank.
39. When an air lift pump is put into service, the starting pressure must equal the depth of water over the footpiece, or over the submerged end of the air pipe.
40. The flow of liquid through a jet pump is maintained by the velocity of the steam jet or the water jet through the nozzle.

Chapter 4

REFRIGERATION

1. (c).
2. Sensible heat is the term applied to heat which raises the temperature of a substance or body, but does not bring about a change in state.
3. (d).
4. The pressure-temperature relationship whereby a stated volume of gas subjected to varying temperatures will show corresponding changes in pressure is the basis of mechanical refrigeration.
5. The 3 processes by which heat transfer takes place from a body of higher temperature to one of lower temperature are: radiation, conduction, and convection.
6. (b).
7. Absorption systems employ heat energy to bring about the changes that produce a refrigeration cycle.
8. The 4 processes that make up the refrigeration cycle in a vapor compression system are: compression, condensation, expansion, and evaporation.
9. In a compression system, temperature difference necessary for heat transfer is provided by having the cycle consist of a high pressure side and a low pressure side.
10. In a compression system, the refrigerant vaporizes on the low pressure side of the system.
11. (a).

12. (b).
13. In large refrigeration plants, a relief valve may be installed between suction and discharge of the compressor to protect it from being damaged if any stoppage in the discharge line causes excessively high pressure to build up on the high pressure side.
14. In late-model domestic-type refrigeration units, the condenser is usually cooled by the natural convection of air passing over it.
15. (c).
16. (d).
17. The function of an automatic expansion valve is to maintain a constant pressure in the cooling coil, while the system is in operation. The thermostatic expansion valve operates to keep the evaporator coil filled with refrigerant while the unit is in operation.
18. In a compression refrigeration system, the liquid refrigerant changes into vapor in the evaporator, by absorbing heat from the product, and thus causing the liquid to boil.
19. The advantage of using a volatile liquid with low boiling point as a primary refrigerant is that it will greatly reduce leaking tendencies and overwork of compressors.
20. (c).
21. Ammonia, rather than Freon 12, is used in large refrigeration plants, because at 5 F and 86 F condensing temperature, its latent heat is 475 Btu's, as compared to 51 Btu's for Freon 12; it therefore requires a much smaller amount of ammonia than of Freon 12, per ton of refrigeration.
22. Methyl chloride is classed as nonpoisonous. It may be explosive in concentrations of as little as 8 percent by volume.
23. The selector dial in small, self-contained refrigeration units is connected with a temperature control close to the evaporator, and a thermal bulb in contact with the evaporator.
24. (b).
25. (d).
26. Evaporative condensers of cold storage plants are located adjacent to outside walls so that they can utilize outside air as a cooling medium.
27. In cold climates, heating is necessary in cold storage plants in order to prevent condensation of the refrigerant in the low pressure side of the system, and to prevent freezing of products in the storage room.

28. An operating log of refrigeration equipment provides a guide, to supervisor and to succeeding operators, of what adverse conditions may occur, and how to correct them.
29. Hermetic motors are those sealed integral with the compressor body.
30. A differential adjustment is one that establishes a different range between cut-in and cut-out temperatures; a range adjustment establishes upper and lower temperature limits, without changing the range between these limits.
31. In the computing of service load on a refrigerator, the 3 factors that must be considered are: temperature difference between inside and outside of cabinet, air changes in cabinet, and lights and motors used in the unit.
32. The effect of moisture freezing on the surface coil is to prevent heat flow.
33. A low pressure (or deep vacuum) is drawn on all new installations in order to purge them of air and moisture before they are put into service.
34. (d).
35. In a system that uses ammonia as a refrigerant, testing for leaks should be done with a sulfur candle.
36. When adding refrigerant to a system, first make sure that you are using the correct refrigerant.
37. If multiple V-belts on one drive are not uniform in length and tension, one belt will carry more than its share of the load, causing it to overheat and wear out.
38. (a).
39. The 2 chief sources of danger to personnel operating a refrigeration system are defective electrical connections, and improper handling of refrigerants.
40. The maximum safe capacity of a gas cylinder is 85 percent.

Chapter 5

AIR CONDITIONING

1. When air at a given temperature holds the maximum amount of moisture possible, it is known as saturated air.
2. (d).
3. (a).

4. Wet-bulb, dry-bulb, and dew-point temperatures of an air parcel are identical when the air is saturated.
5. The 4 ways in which body heat gains occur are: (1) by radiation, (2) by convection, (3) by conduction, and (4) as a byproduct of the physiological processes of the body.
6. (c).
7. (b).
8. Where heat must be added, in a year-round air conditioning system, two factors that can usually be omitted from the computation of heat load are heat gain from personnel, and heat gain from equipment.
9. (d).
10. In an area of conventional height, a sill-mounted unit of 1/2 to 1 hp capacity will cool from 150 to 400 sq ft.
11. (c).
12. (b).
13. A system designed to heat as well as cool the air will have temperature controls, humidity controls, furnace controls, and refrigerant controls.
14. Air filters should be cleaned or renewed periodically, because any accumulation of dirt cuts down the flow of supply air.
15. Freon 22 should not be used in a system intended for Freon 12 unless the system is redesigned.
16. When testing a 115-voltage line with an ammeter and voltmeter testing device, you wire the capacitors in parallel.
17. Sorbent substances are used in air conditioning to extract and hold water vapor, when dehumidification of the air is required.
18. (c).
19. (a).
20. When fans are used for withdrawing hazardous vapors from individual spaces, precautions must be taken to install sparkproof fans and motors, and to prevent concentrations of the exhausted air.
21. Intake air for laundries and other high-temperature work spaces is given a downward direction and relatively high velocity so that it will provide maximum cooling effect for working personnel.
22. Exhaust ducts from kitchen-range hoods must be of cement, asbestos, or metal because of the high temperatures that usually prevail in the outlet air.
23. (c).

24. Cleaning solvents are not recommended for use in the maintenance of a mechanical ventilation system because they introduce the danger of vapor contamination and fire.
25. Painting the frame, rotor, casings, and ductwork of a fan will help to prevent corrosion, and lengthen the life of the fan.

Chapter 6

GALLEY EQUIPMENT

1. (d).
2. If you find a cool spot in the heating element of a heating unit, the probable cause is entrapped air or condensate.
3. You should check the voltage on an electric range at the safety switch, and the amperage at the fuses.
4. The electrical contacts of a heating unit should preferably be cleaned with a fine sandpaper.
5. (b).
6. Oven assemblies should be disconnected from the power supply and checked for defects every two weeks.
7. The preferred method of removing carbon deposits that have accumulated on the heating elements of griddles is by wiping the elements with a cloth dampened with household ammonia.
8. When as much as 30 percent of the orifices of a gas burner have become choked with insoluble deposits, you should replace the burner with a new one.
9. The pressure-reducing valve on a vegetable steamer controls inlet steam; the blow-off valve permits the escape of steam that does not condense.
10. The plunger of a plunger-type valve on a vegetable steamer should be adjusted so that the valve is fully depressed, in order to allow the full complement of steam to enter.
11. When the safety valve on a steamer is found to be defective, the steamer must be taken out of service until the valve can be repaired or replaced.
12. (d).
13. (c).
14. The calibration of the steam gage on a steam-jacket kettle is tested by comparing it with a test gage; the

thermostat is tested by checking it with a mercury thermometer.

15. Use of oil-fired units for a steam table should be avoided because of possible contamination of food by oil fumes.
16. (b).
17. Bare spots on motor-driven foodmixer equipment should be treated with mineral oil or with petroleum jelly.
18. The upper and lower spray assemblies of dishwashing machines must be properly positioned, to ensure that fronts and backs of dishes will receive jets of water, and that wash water and rinse water will not go into the wrong tanks.
19. Lubricants used on dishwashing machines should (1) adhere to surfaces without dripping, (2) retard acid or alkaline action, (3) should not emulsify under a water spray, and (4) must be suitable for operating speeds, pressures, and temperatures.
20. The pumps and impellers of dishwashing machines should be checked at least once a year for signs of severe wear or corrosion.
21. (a).
22. The installation of two compressors in an ice maker permits capacity variation.

Chapter 7

WATER SOURCES

1. The 3 factors that control water supply in a given area are: amount of precipitation, capacity of natural or artificial storage basins, and underlying composition of the region.
2. Surface waters occur in a region either as the result of (1) direct precipitation, (2) being brought down in streams or rivers, and/or (3) the appearance of underground water at the ground surface.
3. (d).
4. The 2 chief factors in the stabilization of the water table for a particular locality are: an impervious layer that results in trapping the water, or a balance between the amounts percolating from above and those flowing away laterally.
5. (c).

6. In tropical regions, rainfall is often collected from roofs, and gutters, or by means of tarpaulins; if the topography permits, catchment basins can be constructed on the side of hills.
7. (b).
8. An artesian spring may be formed where ground water that is under a pressure greater than atmospheric finds an escape passage to the ground surface.
9. (c).
10. The 3 usual types of spring are: outcrop, artesian, and overflow.
11. (a).
12. (a).
13. The success of a dug well depends chiefly upon the distance from ground surface to water-bearing stratum.
14. The slots in the screens placed over aquifers tapped by a drilled well are designed to regulate the amount of water which will flow into the well.
15. (d).
16. (b).
17. The 3 chief causes for pollution of surface water supplies by waterborne diseases are: microscopic plant and animal life brought down from the atmosphere during rainfall, plant and animal organisms picked up by the surface waters from ground surface, and contamination from carelessly arranged drainage.
18. (c).
19. (c).
20. Fluoride, when present to even a small degree in drinking water, can cause mottling of the enamel of the teeth.
21. When you are making a water reconnaissance for a specific area, a study of climatic data for that area should give you a close idea of the amount of water you may expect to find there.
22. For field operations, the minimum safe allowable per capita quantity, under the most adverse conditions is 2 gpcd.
23. A simple method for computing water flow in a surface stream is to time the rate of travel of a twig dropped on the surface; then multiply three-quarters the rate of travel (feet per minute) by the cross-sectional area of the stream.
24. Igneous rocks have practically no porosity, and are therefore poor water carriers unless they contain numerous fractures, bubble holes, or cracks.

25. (b).
26. Drainage conditions are especially important at a water point because if the area is allowed to become muddy, it will add to traffic difficulties.
27. For records kept at a permanent or semipermanent water point, the 3 most essential factors are: daily production, daily distribution, and chlorine residual.

Chapter 8

WATER TREATMENT

1. The 4 purification processes generally employed are: sedimentation, coagulation, filtration, and chlorination.
2. Emergency disinfection of canteen water can be accomplished by adding halozone or iodine tablets.
3. The chemical kit that accompanies each Lyster bag is used for filtering turbid water.
4. (c).
5. (a).
6. Although sedimentation can only remove nonliving suspended solids from water, its use lightens the load on the subsequent purification processes.
7. A long, narrow sedimentation basin is preferable, because cross currents may develop in a wide basin, and retard settling of suspended matter.
8. (d)
9. Alum used as a coagulant tends to lower the pH value of the water, and thus render it corrosive.
10. Backwashing a filter bed redistributes the sand, and also washes off accumulated floc and foreign matter.
11. (a).
12. The normal period between washes for a rapid sand filter is 24 to 48 hours.
13. In storing filtered water, the chief precaution to be taken is against possible recontamination.
14. (d).
15. For water with a low organic content, the recommended chlorine dosage is 8 lb chloride to 1 million gal water.
16. The Navy uses a powdered compound form of chlorine, because water treatment chlorine in gas form is a deadly poison, and chlorine in liquid form reverts to the gaseous state unless maintained under pressure.

17. (b).
18. The Army-type hypochlorinator is powered by the pressure of the water that is being treated.
19. (c).
20. Water should always be chlorinated after distillation, because the distillate can become contaminated through leaks, or by small amounts of raw water entraining with the vapor.
21. The two general types of distilling plants are steam distillation and vapor compression.
22. Distilling plants should be protected in cold weather by the use of protective side panels and shields.
23. The chief disadvantage of distilling plants is the cost of the equipment.
24. Suspended impurities in water are far more dangerous to health than dissolved impurities.
25. (c).
26. (b).
27. (a).
28. Free chlorine is about 30 times as effective as chloramines in destroying bacteria when the pH value of the treated water is 7.0.
29. Normally, chlorination becomes less effective as the pH value of water increases.
30. A newly constructed well, or one that has been cleaned out, must be pumped to waste until the water is free from turbidity.
31. Hypochlorination units are primarily used for the emergency disinfection of water.
32. The 3 chief factors in the computation of proper chlorine dosage are: the volume of water to be disinfected, the contact time, and the amount of organic chlorine-consuming matter present in the water.
33. When a distribution system is to be constructed at a new base, the first requirement is that a safe and continuous supply of water will be available.
34. Canvas tanks used for storage of water should be placed on raised platforms so that air can circulate beneath them; placing them on platforms also helps in gravity-feeding of water from storage to distribution.
35. When kerosene or dry-cleaning solvents are being used, keep the work space well ventilated, and take precautions against spilling the cleaning agent, or exposing it to flame.

Chapter 9

SEWAGE AND REFUSE DISPOSAL AND PEST CONTROL

1. (c).
2. If feasible, at a temporary base, lead the water from lavatories and showers to a dosing tank, then utilize it to flush the latrine channels.
3. In constructing latrines, the chief thing to guard against, after water pollution, is the danger of fly breeding.
4. (b).
5. Cracks in a latrine box can be made fly-tight by the application of cloth packing or strips of wood.
6. (d).
7. The 2 disadvantages of chemical toilets are the difficulties involved in keeping chemical supplies on hand, and the danger of chemical burns to personnel.
8. (a).
9. Flushing into a sewage system is considered the most sanitary method of removing liquid wastes from the vicinity of habited areas.
10. Where the soil is pervious, and the amount of liquid waste is small, the waste can be passed through settling tanks and then absorbed into the soil.
11. To ensure protection against traffic and frost, the pipes of a sewage system should be covered to a depth of 2 ft or more.
12. (d).
13. An excessively diluted flow in a sewer usually indicates that there is a seepage of storm water or ground water into the sewage system.
14. The flow of sewage through a settling tank must be held at a low velocity to give the heavy matter time enough to settle.
15. The two disadvantages of septic tanks are: (1) the gases produced may raise the digesting solids and carry them out with the effluent, and (2) the tanks cannot accomplish a degree of purification that would satisfy good health requirements.
16. The effluent from a combined settling and digestion tank should be spread on sand beds to dry, and then placed in a disposal pit.
17. (d).
18. The use of evaporation beds is most practicable in hot, dry climates.

19. One part of raw sewage should be mixed with at least 100 parts of fresh water; one part of settled sewage with at least 70 parts of water; one part of filtered sewage with at least 10 parts of water.
20. When an outfall sewer empties into the ocean, the point of discharge should be in deep water, so that prevailing currents will not bring polluted water back to shore.
21. (a).
22. The 3 most important secondary treatment processes are: trickling filter, activated sludge, and sand filtration.
23. The treatment process in which sewage is intermittently applied, by means of spray nozzles or rotating arms, over a bed of coarse stones, is known as the trickling filter process.
24. In hot, dry weather, you might chlorinate completely treated sewage in a receiving stream in order to delay decomposition until the sewage has been widely dispersed.
25. (d).
26. In a sewage treatment plant, the 2 main sources of potentially explosive gas are leakage from the sewer system, and decomposition of sewage solids in the digestion tanks.
27. The waste around an activity should be removed and disposed of daily, to ensure sanitation, orderliness, and the health of personnel.
28. Liquid or semiliquid combustible waste products can sometimes be utilized as road-conditioning materials.
29. (b).
30. Before deciding to dispose of garbage by dumping it at sea, make sure that there is no danger of polluting adjacent shores, or of having the refuse washed back by currents.
31. The 2 factors by which the capacity of an incinerator is determined are: (1) weight and nature of the waste, taken for a period of several days and then averaged for a 24-hr period, and (2) the ability of the furnace to dispose of this 24-hr average amount within 8 hr.
32. Excessive amounts of air allowed to enter the incinerator furnace when it is in operation will lower the furnace temperature.
33. At military installations, mosquito control is important because mosquitoes reduce personnel efficiency, and may transmit yellow fever, malaria, and other diseases.

34. In using a malathion concentrate for fly bait, be careful not to inhale it, or to have it come into prolonged contact with your skin.
35. (a).

Chapter 10

FOREMANSHIP RESPONSIBILITIES

1. The 3 disadvantages of overordering supplies are: undue burden on storage facilities; immobilizing items needed at another activity, ultimate waste of materials.
2. (c).
3. The form you will most frequently use in requisitioning materials from your activity supplies is the DD Form 1150, Request for Issue or Turn-In.
4. When you are preparing a requisition, consult the Navy Stock List for a detailed description of the item.
5. (a).
6. According to the text, the petty officer who must plan and supervise technical duties should have (1) knowledge of the technical fields involved, (2) ability to pass this knowledge on to others, (3) skill in dealing with people, and (4) willingness and ability to develop improved methods of doing the work.
7. The best means of appraising the abilities of lower-rated men will probably be your supervision and training of them on actual jobs.
8. (d).
9. (b).
10. A training program should be very closely tied in to the needs of an activity, and should not be carried on where the men obviously know how to perform their duties.
11. The 4-step method of instruction consists of preparing, showing, testing, and a follow-up supervising.
12. It is not necessary to have your men perform every job procedure according to a strict pattern; allow them some freedom in their work, provided quantity and quality are satisfactory.
13. Your first step in dealing with a man whose job performance is unsatisfactory should be to seek out the underlying causes.
14. In putting a man in charge of a particular job, you should delegate to him enough authority to meet the

demands of the specific situation; but you cannot delegate your responsibility.

15. A scheme of breaking down jobs into a sequence of simple operations, and a training timetable, will help you in systematizing job procedures and assigning capable men.
16. (c).
17. Improved work methods may result in 3 important benefits: (1) SAVINGS in time, material, and equipment, (2) EASE of learning and performance, and (3) greater SAFETY.
18. It is your duty to instruct your men in the accurate and periodic recording of data for logs and other operational reports; and to inspect and supervise from time to time, to ensure that they are following your instructions.

Chapter 11

SMALL UNIT COMBAT TACTICS

1. For combat purposes, a full-strength construction battalion is divided into one headquarters company and four rifle companies.
2. A rifle company consists of three to five platoons, including a headquarters platoon and a machine gun or heavy weapons platoon. A rifle platoon consists of platoon headquarters and four rifle squads. A rifle squad consists of a squad leader and three fire teams. A fire team consists of a fire team leader, an automatic rifleman, an assistant automatic rifleman, and a rifleman.
3. During combat, a rifle squad leader carries out the orders of the platoon commander, maintains fire discipline, maneuvers the squad, and exercises control of its fire.
4. The basic rifle squad formations are (1) squad column, fire teams in column or fire teams in wedge, (2) squad wedge, fire teams in wedge, (3) squad vee, fire teams in wedge, (4) squad echelon right or left, fire teams in wedge, and (5) squad line, fire teams in wedge or fire teams in skirmishers right and left.
5. The column is the rifle squad formation which is most vulnerable to enfilading fire from the front.
6. Squad echelon right is the basic rifle squad formation which makes it possible for the squad to deliver

maximum fire both to the front and on the right flank.

7. The general duties of each member of a fire team during combat are as follows. The fire team leader carries out the orders of the squad leader, maintains fire discipline, maneuvers the fire team, exercises control of its fire, and serves as rifleman and grenadier. The automatic rifleman carries out the orders of the fire team leader and is responsible for the effective employment of the automatic rifle. The assistant automatic rifleman covers the automatic rifleman, supplies the automatic rifleman with ammunition, and assumes the place of the automatic rifleman if necessary. He also serves as general rifleman, scout, and grenadier. The rifleman serves as general rifleman, scout, grenadier, and security element.
8. The four basic fire team formations are (1) wedge, (2) column, (3) skirmishers left, and (4) skirmishers right.
9. Skirmishers right/left allows the use of maximum fire to the front.
10. The wedge formation provides all-around protection and readiness for action in any direction.
11. The automatic rifleman is normally an interior man in the fire team formation.
12. The six basic elements in a fire command are (1) alert, (2) direction, (3) target description, (4) range, (5) target assignment, and (6) fire control.
13. If a squad leader desires to obtain maximum shock and surprise effect by a sudden, simultaneous fire of all weapons, he prefaces the command COMMENCE FIRING with the command AT MY COMMAND or AT MY SIGNAL.
14. The whistle signal for CEASE FIRING is three long blasts.
15. (1) To signal SQUAD ALERT, extend one arm and hand (palm-down) toward the squad leader, and move the hand up and down by pivoting on the wrist. (2) To signal AS SKIRMISHERS, extend the arms horizontally, with hands held palms-down. (3) To signal CHANGE DIRECTION TO THE RIGHT, place the right hand, palm-down, in front of the left shoulder, holding the forearm horizontal, and then swing the forearm in a horizontal plane until the arm and hand are pointing in the new direction. (4) To signal ENEMY IN SIGHT, hold the rifle horizontally above the head, with the arm or arms extended as if guarding the head. (5) To signal COMMENCE FIRING,

extend one arm horizontally forward, with hand palm-down, and move the arm and hand in a series of wide circles. (6) To signal CEASE FIRING, place the arm approximately in saluting position, but with hand held palm-forward, and describe a series of arcs by passing the hand back and forth across the face.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

UTILITIES MAN (UT)

Quals Current Through Change 11

General Rating (applicable to PO1 and CPO only)

Scope

Utilities men plan, supervise, and perform tasks involved in installation, maintenance, and repair of heating, water distribution, and treatment systems, air-conditioning and refrigeration equipment, and sewage disposal facilities: Schedule and evaluate installation and operational tasks and routines; oversee and perform tasks in procurement and issue of supplies and spare parts; prepare records and reports; draw up or alter schematics; train assistants in installation, operation, and repair procedures and techniques.

Service Ratings (applicable to PO3 and PO2 only)

Scope

UTILITIES MAN P (Plumber) . . . . UTP

Assemble and install piping, equipment, and facilities to provide fuel, air, water and waste disposal; cut, bend, and fit commonly used piping; make pipe joints by threading, caulking, fitting, or soldering; install fixtures such as toilets, sinks, valves, and traps; clean and repair waste disposal and piping systems; cover pipe with insulative and protective materials.

UTILITIES MAN B (Boilerman) . . . . UTB

Install, operate, service, and repair steam boilers of advanced base type; regulate steam pressures and fuel supply; operate related machinery and record pressures of steam, fuel, oil, air, and feed water; test boiler and feed water; test boiler for leaks; clean fire and water sides; replace tubes; cut, fit, and install boiler castings and gaskets; test fuel oils; repair and calibrate gages; install and repair galley equipment.

UTILITIES MAN A (Air Conditioning) . . . . UTA

Install, operate, service, and repair air-conditioning and refrigeration equipment; maintain required suction and discharge pressures on compressors and pumps; repack valves; fit pipe; inspect refrigeration systems for leaks; purge air and charge refrigeration systems, clean and defrost refrigeration coils; and regulate temperatures of ice boxes, cold storage spaces, and air-cooled compartments.

UTILITIES MAN W (Water and Sanitation) . . . . UTW

Install, operate, service, and repair water distillation and purification equipment and pumps; operate water supply installations, pumping stations, and sewage disposal plants of advanced base type; install, operate, and service prime movers used to supply utilities; distill and purify water; make chemical tests to determine safeness and potability of water.

PATH OF ADVANCEMENT TO WARRANT OFFICER AND LIMITED DUTY OFFICER

Utilities men advance to Warrant, Civil Engineer Corps and/or Limited Duty Officer, Civil Engineer Corps.

Navy Enlisted Classification Codes

For specific Navy enlisted classifications included within this rating, see Manual of Navy Enlisted Classifications, NavPers 15105 A, codes UT-6100 to UT-6199.

Qualifications for Advancement in Rating

1. Qualifications for advancement to a higher rate include the qualifications of the lower rate or rates in addition to those stated for the higher rate.
2. Practical factors will be completed before recommendation for participation in the advancement examination. (Bureau of Naval Personnel Manual, NavPers 15791, Articles B 2327 and C 7201.)
3. Knowledge factors and knowledge aspects of practical factors will form the basis for questions in the written advancement examinations.

Qualifications for Advancement in Rating	Applicable Rates				
	UTP	UTB	UTA	UTW	UT
A. PLUMBING AND PIPE FITTING					
1.0 PRACTICAL FACTORS					
1. Cut and thread pipe; make threaded mechanical and caulked pipe joints . . .	3	3	3	3	--
2. Prepare and place pipe lagging and other insulating and protective materials . . .	3	3	3	--	--
3. Bend, fit, and join copper tubing	3	--	3	3	--
4. Work as a crew member in laying sewer, drainage, and utilities distribution pipe to grade . . .	3	--	--	--	--
5. Lay sewer, drainage, and utilities distribution pipe to grade . . .	2	--	--	--	--
6. Work as crew member in installation of plumbing systems including fixtures	3	--	--	--	--
7. Install plumbing systems including fixtures . . .	2	--	--	--	--
8. Perform and interpret results of mechanical tests used in plumbing and utilities distribution and collection systems. . .	2	--	--	--	--
9. Maintain and repair plumbing and utilities distribution and collection systems . . .	2	--	--	--	--
2.0 KNOWLEDGE FACTORS					
1. Standard color coding and markings used on shore piping systems	3	3	3	3	--
2. Methods of pipe and tubing identification and measurement . . .	3	3	3	3	--
3. Characteristics and types of utilities distribution and collection systems . .	2	--	--	--	--
4. Methods of installing, maintaining, and repairing low-pressure compressed air systems . . .	2	--	--	--	--
B. FURNACES, BOILERS, AND PRESSURE VESSELS					
1.0 PRACTICAL FACTORS					
1. Clean watersides and firesides, clean and adjust burners, and set and adjust valves of steam boilers of advanced base type . . .	--	3	--	--	--
2. Perform routine boiler and feed water tests . . .	--	3	--	--	--

Qualifications for Advancement in Rating	Applicable Rates				
	UTP	UTB	UTA	UTW	UT
B. FURNACES, BOILERS, AND PRESSURE VESSELS—Continued					
1.0 PRACTICAL FACTORS—Continued					
3. Use power-driven equipment to clean boiler tubes	--	3	--	--	--
4. Operate, regulate, adjust, and keep operational logs for stationary steam boilers	--	3	--	--	--
5. Perform and interpret results of mechanical tests made on boilers and pressure vessels	--	2	--	--	--
6. Install and repair furnace floors, walls, and linings for steam boilers of advanced base type	--	2	--	--	--
7. Repair air and water leakage in furnaces, pipelines, pipe fittings, and other boiler parts	--	2	--	--	--
8. Replace defective boiler tubes	--	2	--	--	--
9. Install stationary steam boilers	--	2	--	--	--
10. Install and repair galley equipment such as oil-fired ranges and ovens, coppers, steam kettles, steam traps, and steam tables and dishwashing machines	--	2	--	--	--
11. Test, troubleshoot, and adjust or repair electrical and mechanical control systems	--	--	--	--	1
2.0 KNOWLEDGE FACTORS					
1. Construction, parts, and operation of steam boilers of advanced base type and their auxiliary equipment	--	3	--	--	--
2. Classifications and tests of heating fuels	--	2	--	--	--
3. Principles and methods of boiler and feed water treatment	--	--	--	--	1
C. REFRIGERATION AND AIR CONDITIONING EQUIPMENT					
1.0 PRACTICAL FACTORS					
1. Operate, adjust, service, and keep operational logs for refrigeration and air-conditioning equipment	--	--	3	--	--
2. Make minor repairs to, and perform preventive maintenance on refrigeration and air-conditioning equipment and systems	--	--	3	--	--

Qualifications for Advancement in Rating	Applicable Rates UTP	UTB	UTA	UTW	UT
C. REFRIGERATION AND AIR CONDITIONING EQUIPMENT—Continued					
1.0 PRACTICAL FACTORS—Continued					
3. Perform routine halide torch tests for leaks in refrigeration and air-conditioning equipment; check for non-condensible gases	--	--	3	--	--
4. Purge air from systems; dehydrate, test, and charge refrigeration equipment with proper types of refrigerants	--	--	3	--	--
5. Test, troubleshoot, adjust, and repair refrigeration and air-conditioning equipment including control systems. .	--	--	2	--	--
6. Perform and interpret results of chemical and mechanical tests used in refrigeration and air-conditioning equipment	--	--	2	--	--
7. Install refrigeration and air-conditioning equipment	--	--	2	--	--
2.0 KNOWLEDGE FACTORS					
1. Principles of refrigeration cycles; characteristics of refrigerants	--	--	3	--	--
2. Purposes, construction, and operation of refrigeration and air-conditioning units	--	--	3	--	--
D. WATER TREATMENT AND SANITATION					
1.0 PRACTICAL FACTORS					
1. Operate, adjust, service, and keep operating logs on water distribution, purification, and sewage disposal equipment of advanced base type	--	--	--	3	--
2. Perform routine tests on water and sewage	--	--	--	3	--
3. Make minor repairs and perform preventive maintenance on water distribution and purification equipment of advanced base type, excluding prime movers	--	--	--	3	--
4. Perform major repair and overhaul of water distillation and purification equipment of advanced base type, excluding prime movers	--	--	--	2	--
5. Install and operate water distillation, purification, and sewage treatment plants	--	--	--	2	--
6. Perform and interpret results of tests used in water treatment and sanitation	--	--	--	2	--

Qualifications for Advancement in Rating	Applicable Rates				
	UTP	UTB	UTA	UTW	UT
D. WATER TREATMENT AND SANITATION—Continued					
2.0 KNOWLEDGE FACTORS					
1. Water purification obtained by filtration, sedimentation, distillation, flocculation, and chemical treatment	--	--	--	2	--
2. Principal sources of water for advanced bases and comparative safeness of each	--	--	--	--	1
E. GAGES AND VALVES					
1.0 PRACTICAL FACTORS					
1. Grind in or replace valve disks and seats	3	3	3	3	--
2. Test, adjust, and recalibrate high- and low-pressure gages	--	--	--	--	1
2.0 KNOWLEDGE FACTORS					
None.					
F. PUMPS, COMPRESSORS, AND PRIME MOVERS					
1.0 PRACTICAL FACTORS					
1. Operate and perform operator maintenance on prime movers used to furnish utilities at advanced bases	3	3	3	3	--
2. Operate, adjust, service, and perform preventive maintenance on pumps and compressors used at advanced bases for:					
a. Water supply, sanitation, and water purification	--	--	--	3	--
b. Boilers	--	3	--	--	--
c. Refrigeration and air-conditioning	--	--	3	--	--
d. Water distribution	3	--	--	--	--
3. Make major repairs to pumps of advanced base type for:					
a. Water treatment and sanitation . . .	--	--	--	2	--
b. Boilers	--	2	--	--	--
c. Refrigeration and air-conditioning	--	--	2	--	--
d. Water distribution	2	--	--	--	--
2.0 KNOWLEDGE FACTORS					
None.					

Qualifications for Advancement in Rating	Applicable Rates				
	UTP	UTB	UTA	UTW	UT
G. TOOLS					
1.0 PRACTICAL FACTORS					
1. Select and use hand and power tools, equipment, and materials commonly employed in:					
a. Plumbing	3	--	--	--	--
b. Refrigeration and air-conditioning	--	--	3	--	--
c. Boilers	--	3	--	--	--
d. Water treatment and sanitation . . .	--	--	--	3	--
2.0 KNOWLEDGE FACTORS					
None.					
H. DRAWINGS AND SKETCHES					
1.0 PRACTICAL FACTORS					
1. Read simple working drawings and sketches	3	3	3	3	--
2. Work from plans and specifications . .	2	2	2	2	--
2.0 KNOWLEDGE FACTORS					
None.					
I. SAFETY					
1.0 PRACTICAL FACTORS					
None.					
2.0 KNOWLEDGE FACTORS					
1. Safety precautions and procedures to be observed while working on plumbing, refrigeration, air conditioning, boilers, water treatment, and sanitation	3	3	3	3	--
2. First-aid procedures used when exposed to refrigerants and toxic fuels . .	3	3	3	3	--
3. Selection and use of fire fighting equipment	3	3	3	3	--
J. FOREMANSHIP					
1.0 PRACTICAL FACTORS					
1. Prepare inspection and progress reports, job orders, and material requisitions; stow and account for spare parts	--	--	--	--	1

Qualifications for Advancement in Rating	Applicable Rates				
	UTP	UTB	UTA	UTW	UT
J. FOREMANSHIP—Continued					
1.0 PRACTICAL FACTORS—Continued					
2. Make equipment and material estimates from drawings, sketches, and specifications	--	--	--	--	1
3. Supervise and train personnel engaged in installation, operation, maintenance, and repair of plumbing, water and steam distribution, air conditioning, water treatment, and sanitation systems, and boilers	--	--	--	--	1
4. Develop operational procedures and prepare reports for utility equipment and systems	--	--	--	--	C
5. Conduct training programs to qualify personnel for advancement in rating including crosstraining of service rating personnel for advancement to the general rating	--	--	--	--	C
6. Control site deployment of materials and equipment	--	--	--	--	C
7. Train individuals and drill crews in safe and expeditious execution of assigned tasks	--	--	--	--	C
8. Direct and coordinate composition and efforts of crews	--	--	--	--	C
9. Direct general job operations involving plumbing, water and steam distribution, air conditioning, boilers, water treatment, and sanitation systems	--	--	--	--	C
2.0 KNOWLEDGE FACTORS					
1. Principles and techniques of supervision and job control	--	--	--	--	1
K. DEFENSIVE TACTICS					
1.0 PRACTICAL FACTORS					
1. Maneuver fire teams into various formations by the use of hand and arm signals	--	--	--	--	C
2.0 KNOWLEDGE FACTORS					
1. Employment of fire teams in defensive positions	--	--	--	--	C
2. Instructions to be given perimeter guards	--	--	--	--	C

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